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A Critical Analysis of the Use of Non-Metric Traits for Ancestry Estimation among Two North American Population Samples

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I am submitting herewith a thesis written by Corrine Leeann Vitek entitled "A Critical Analysis of the Use of Non-Metric Traits for Ancestry Estimation among Two North American Population Samples." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

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A Critical Analysis of the Use of Non-Metric Traits for Ancestry Estimation Among Two North American Population Samples

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ABSTRACT

The use of diverse morphological features, or traits, of the skeleton for the estimation of ancestry is an important part of the forensic anthropologist's toolkit for medico-legal death investigations. This study re-evaluates the classic techniques historically used to estimate ancestry within the United States in human crania. It emphasizes the possible inclusion of secular change in the prevalence of traits when comparing well documented modern skeletal material to a comparable sample of an earlier period.

The aim of this study is to critically analyze the use of previously established nonmetric cranial traits associated with ancestry estimation among two male North American samples: Euro Americans and African Americans. This work evaluates the relative utility of each trait as well as assesses the potential influence of short-term evolution, or secular change, on the distribution and expression of each trait. Crania (n=441) were used from three sources: The William M. Bass Donated Collection (n=190) and LSU (n=34) provided a modern sample and The Robert J. Terry Collection (n=217) a historic sample. For each trait, frequencies were tabulated and chi square tests were conducted to assess significant change differences between groups and for secular change within each group. This study demonstrates that it is possible to discern statistically significant differences between the two groups in some traits while not in others. Secular change was observed in both the mid-facial region of the crania as well as traits typically regarding as reflecting cranial robusticity in both.

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CHAPTER 1
INTRODUCTION

The use of physical morphology to catalogue individuals and populations is not a new phenomenon in anthropology (Birdsell 1987; Howells 1989; Sauer 1992; Harris 1992; Brues 1990; Rhine 1990; Hefner 2009; Relethfold 2009). In early American anthropology, human variation was viewed through the lens of biological race. Biological race can generally be thought of as geographically patterned observed phenotypic variation within a species (Jurmain et al 2010) and has been used analogously to subspecies (Marks 2008). "Race" is often thought of as a discrete category, meaning that membership is exclusive for individuals to belong only to one group. Templeton (1998) defines biological race as "a distinct evolutionary lineage within a species. This definition requires that a subspecies be genetically differentiated due to barriers to genetic exchange that have persisted for long periods of time; that is, the subspecies must have historical continuity in addition to current genetic differentiation." In this context, these lineages are exclusive and exist without an overlap. Today, it has been established that any physical differences between populations can be attributed to a confluence of genetic and environmental factors. The human species is polytypic, a term used to describe populations of species that differ in the expression of one or more traits but it says nothing about the exclusivity of a certain trait to any population. Overlap in trait expression is both expected and observed. Biological populations, in this context, are communities of human beings that share a common gene pool and in which mates are typically found (Jurmain et al 2010). These populations exist in local or sometimes global geographic areas that distinguish themselves as a more or less distinct group by genetically transmitted physical characteristics (Littlefield et al 1982; Fuentes 2008; Birdsell 1987; Smay and Armelagos 2000). Therefore, "race," as a categorical construct, is much more of a social phenomenon than a biological one. Though built in part on perceived biological differences among populations, social race categories are culturally constructed and maintained for political and social purposes. Gravlee (2009) defines it as “a worldview: a culturally structured, systematic way of looking at, perceiving, and interpreting reality.”

Usage of the term “race” in anthropology has been slowly discontinued in the last decade, largely because its use has fueled the idea that humankind can be separated into discrete categories. Instead, there has been growing use of the term “ancestry.” Unfortunately, ancestry is not well defined in anthropology other than being accepted as an alternate term (Smay and Armelago 2000). Does changing terminology change the method or the connotation implied by the methods?

The core concept behind ancestry is in the origins of an individual. It denotes a biogeographical region (or regions) of origin for an individual’s (or group of individuals’) ancestors. This overlaps with the definition of race; ancestry is still culturally constructed to a degree though it does include a perceived (whether valid or not) genetic, heritable component. Ancestry can be estimated to a larger geographic region but not pinpointed specifically to a national identity. While ancestry will be used in this study to adhere to norms in the field, it is important to note that the ancestral categories often used in the United States have analogous counterparts with previously used racial groups. It is important to discuss and understand exactly what it is that forensic anthropologists are measuring in their estimations of ancestry.

It is the aim of the present study to re-examine the utility of nonmetric traits in the ancestry estimation of unknown individuals. Several questions that have been left largely assumed by early researchers will be addressed. First, are there significant differences in morphological, nonmetric trait distribution across two ancestry groups in North America – Euro

American and African American males – and are any of these differences discernible and exclusive to these groups? These two groups were chosen due to the availability of specimens for study and due to the social categories given to groups and the population distribution of the United States, an issue that will be addressed below. Secondly, have the distribution of nonmetric traits exhibited any significant secular trends over time in the United States that would change the usage of traits in a modern context?

A nonmetric examination is typically accomplished through a visual assessment of morphological characteristics of a given bone (hence being given the name "morphoscopic traits" in some new literature), commonly the cranium and mandible in the case of ancestry (Rhine 1990; Sauer 1992; Gill 1995; Reichs 1999; Hefner 2009). This is done by careful examination of nonmetric variation in skeletal material. These are catalogued as a visual identification of traits that differ between groups and are generally not measured on a continuous scale (Byers 2001). They are often difficult to identify for a number of reasons, including the fact that they vary from one individual to another (Saunder 1989; Ousley et al 2009). A number of nonmetric traits commonly cited in reference material and used as part of an "oral tradition" of forensic anthropological instruction and practice are predominantly anecdotal or come from small samples (Brues 1990; Rhine 1990). With the growing movement for all scientific testimony to withstand the Daubert Standard for expert testimony (NAS 2009), it is now imperative to provide well-documented and well-established standards and practices within the field. This includes the use of nonmetric traits.

In the interest of standardization and furthering accurate methodology in forensic anthropology, it is important to analyze the possibility of secular change: short-term change generally occurring across one or two generations. While secular change has been explored in the crania metrically (Jantz 2001; Jantz and Meadows Jantz 2000), with geometric morphometrics (Westcott and Jantz 2005) and in the post-crania (Spadley and Jantz 2011), secular change in nonmetric traits, particularly in those that relate to ancestry estimation, is largely unexplored. Current methods in the field reflect historic samples or, at best, historic samples and modern samples studied together. There has been little interest in studies that establishes whether or not the changes seen reflected in the cranial shape have a bearing on the nonmetric traits used for forensic identification.

This study explores the possibility of secular change in these traits for the further purpose of understanding change in human variation and to provide a further push for the standardization of nonmetric methods. Outdated methodology using samples that do not reflect trends in the current United States population can lead to difficulty in correctly estimating ancestry in that population. Worse, it can lead to the possibility of misclassification of ancestry in medico-legal investigations. Growth and development respond to environmental conditions (Jantz and Meadows Jantz 2000); as the understanding of race and ancestry has changed in the last 50 years, so has the social and political environment. These changes in environment may directly contribute to change in these "racial" groups. If secular change is occurring in nonmetric variation, this should be taken into consideration when choosing samples used to devise methods. Additionally, it should factor into the methods themselves, as methodology should change as populations change. Forensic anthropology should be a reflection of the current populations, not forcing outdated concepts to fit current understanding of human variation. It is imperative for scientists to challenge accepted techniques practiced without standardized methodology just as it is important to change methodology when there is the possibility of change in the observed phenomenon. In this case, change in nonmetric traits could lead to change in a forensic anthropologist's ability to classify ancestral affinity.

1.1 Race, Human Variation, and Anthropology

Historically, biological race was considered to be a real phenomenon and therefore its diagnosis could be used to describe and categorize human variation (Littlefield et al 1982; Relethford 2009; Smay and Armelagos 2000; Sauer 1992). The 1960s saw a shift in thinking from a discrete categorical, typological approach in racial determination to a complex view of human variation based upon a congruence of social, environmental and genetic factors. Understanding this shift is crucial to understanding the need for are-evaluation in forensic anthropology as well.

The concept of race rose concurrently with the age of colonialism and the rise of the scientific revolution (Harris 1992; Shreeve 1994; Marks 2008). Humankind has most likely always carried an interest in distinguishing groups from one another (Anderson 1991;Harris 1992) and recent studies have shown that even primates and other mammals have demonstrated tendencies to discriminate and categorize things (Kriegeskorte et al 2008). For humans, the ability to separate groups into kinds based on discerning criteria can be a useful trait as it allows for maximization of memory and adaptability (Anderson 1991). However, when social privilege is given to the exclusion of certain groups and membership relies upon physical appearance, this is both discriminatory and oppressive. For centuries, this was largely done in the context of "folk racism" or popular discrimination of one group against another and largely in an informal manner (Harris 1992). Prior to the rise of British colonization "nations had never rewarded their wise men to prove that the supremacy of one people over another was the inevitable outcome of the biological laws of the universe" (Harris 1992:81).

Scientific racism partly emerged from the Platonic quest for an ideal type that was prevalent in the 18th and 19th centuries (Gill 1990). The inherent assumption was of European cultural and physical superiority over the countries and peoples they were colonizing. At that time, races were categorized by skin color, facial feature shape and hair form to justify fundamental taxonomic division of the human species; Swedish physician and father of the modern taxonomy Carl Linneaus defined four human races in the tenth edition of Systemae Naturae in 1758: *Americanus, Asiaticus*, *Africanus*, and *Europeanus*,. German physician, anatomist, and physical anthropologist Johann Friedrich Blumenbach described five, with colors he attributed to each group: Caucasian (white), Mongolian (yellow), Malayan (brown), Ethiopian (black), and American (red), in 1776 (Gill 1990). These races were considered to be pure and distinct from one another at their genetic origin. Any gradation between them was attributed to mixing of “pure races” instead of evidence of natural clines. This typological view was both created and propagated by some of the greatest scientific minds throughout much of the eighteenth century (Gill 1990; Stewart 1979).

Popularized by European philosophers and anthropologists, Eurocentric views sparked a rise in racial determinism, or the belief that all potential physical, intellectual ability, and social status was completely determined by preexisting ‘racial conditions,’ precluding such things as agency and free will. These beliefs were evident in the writings of famous philosophers of the time like Voltaire, David Hume, and Edward Long, all of whom espoused that there were very distinct differences among racial groups that went beyond, but were nevertheless reflected by, skin color. Intelligence, character, and capabilities of racial groups were viewed unfavorably when compared against the European ideal.

Racial determinism was eventually challenged with the acceptance of Darwinian thought, separation from the religious underpinnings of biological differences and a better understanding of natural selection and other evolutionary processes (Harris 1992; Littlefield et al 1982). Gradually, the theory of human beings as a cohesive species overtook these earlier views. As early as 1952, Claude Levi-Strauss stated that the original sin of physical anthropology was the idea that a biological view of race was relevant to our understanding of human culture (Smay and Armelagos 2000).

Yet the use of categorical classification remains prevalent in biological anthropology while the meaning and understanding of the variations used to categorize is increasingly debated (Gill 1990). With a rise in use of genetics in anthropology as a means to study populations in the latter half of the twentieth century, the concept of race underwent further shifts. The historical views of biological race were challenged and criticized to a greater extent (Littlefield et al 1982; Sauer 1992; Relethford 2009). Differences between populations were at the time referred to in terms of "clines," or slopes which can describe the gradual changes in physical characteristics, such as skin color, over a geographical landscape (Livingstone 1962). These geographically based clines provided a picture of gradual variation across a single species and can account for much of the physiological difference between population groups (Brace 1995; Livingstone 1962).

In 1972, geneticist Richard Lewontin published "The Apportionment of Human Diversity' and dismantled much of the quantitative basis for race. This study analyzed the amount of genetic variation that could account for physical differences most often associated with race. Using biochemical markers for nine blood groups and eight serum proteins (17 genetic markers), Lewontin examined variation in seven categories associated with classic racial groupings: Causcasians, Africans, Mongoloids, South Asian Aborigines, Amerinds, Oceanians, and Australian Aborigines. Of the genetic differences found in the groups, 85.4% were found to be within a population, 8.3% were found between populations within a category, and 6.3% was found to differentiate between the categories (Lewontin 1972). This study, and studies that followed (Livingstone et al 1982; Long and Kittles 2003; Marks 2011), were proof that racial categories with a biological basis analogous to subspecies and based upon genetic differences have decreasing validity in anthropology. Today, race is used in a context that has become a more complex issue of socioeconomics, culture, and environment.

There is no gene that defines race or provides categorical group membership into a biologically derived subspecies (Dupri 2008). Nor are there any single Mendelian genes that control skin color. Like many other traits that are typically used to identify race, skin color is a continuously variable character trait that is associated with multiple genetic loci. Race is not a biological trait dictated by a certain set of genetic markers that can be used to separate human beings into kinds or categories. By and large, the concept of Mendelian genetics has no place in the concept of race at all (Dupri 2008). Genetic variation in humankind is not as simple as one-gene equated with one-trait. In fact, it has been shown that groups residing near the edge of these major population groupings typically have ancestral roots from multiple genetic clusters (Bolnick 2008). While the phenotypic features like skin color or hair form are biological traits, the variability of these phenotypic expressions is extremely high. There is no perfect shade of white skin to qualify as Caucasian nor is there a specific shade of brown that would qualify one individual as being Asian, Indian, Latino, Native American, or African American.

While the contribution of genetic research should not be ignored, the assignment of race in forensic anthropology does not necessarily carry implication about the specifics of genetic differentiation (Fieldman and Lewontin 2008). Currently, anthropologists see differentiation among populations as mostly cultural. There is very little variation that cannot be explained without the usage of racial terminology. Yet the use of categories as a tool for classification purposes remains prevalent in biological anthropology even as the biological meaning of these classifications no longer holds true. Gill (1990) suggests "this is because it is so much easier to carefully observe and classify diversity in nature than it is to actually understand it," though this explanation alone does not explain or justify the use of the concept or its validity in applied forensic anthropology.

1.2 Forensic Anthropology and Race

While anthropology's official stance on biological race is its non-existence, there remains some question of how the physical differences between groups are used within forensics, an applied subfield of biological anthropology. Smay and Armelago (2000) outline four common viewpoints among forensic anthropologists with respect to race: 1) race is a discrete, natural category, 2) race is a concept accurate enough for applied work, 3) the non-existence and non-utility of race, and 4) race is a necessary evil.

The view of race as a natural category is the most uncritical of those presented (Smay and Armelagos 2000). In this category, researchers examine race as a default, usually with an *a priori* set of assumptions that come with categories established (Rhine 1990; Ossenberg 1976; Carpenter 1976; Wiljsman and Neves 1986). Racial categories are clear and obvious to the point that they do not require investigation for validity, meaning, or debate. Smay and Armelagos refer to it as "inherited along with other conventional wisdom" (2000). Rhine (1990) shows this most obviously in his study designed to examine morphological features of the skull. The study itself will be explored later in the text but in the article Rhine has the unequivocal view that categorical race does exist and that the job of a forensic anthropologist includes placing humans within a discrete racial category. This reflection is, to many researchers (Smay and Armelagos 2000; Long and Kitties 2003; Relethford 2009), holding anthropology back by failing to acknowledge the gap between practice and theory.

The second approach to race, that of moderation with compromise among the other views presented, considers race as an imprecise way to describe human variation but is accurate when doing applied work. Brues (1993) is a proponent of this view in forensic anthropology and within theoretical paradigms. Smay and Armelago (2000) liken this approach to the current opinion on Newtonian physics – the simple laws are known to be inaccurate but they allow for more precise predictions and measurements than without. It is well established that human variation is far more complex than the original race concept: assigning the entirety of the world's populations into discrete categories is impossible; yet it remains simpler to do this than to work without a framework.

In the next approach to race, that of the nonexistence and non-utility of the concept entirely, proponents argue that the concept of discrete kinds must be abandoned entirely. Human variation is too broad and complex to be categorized neatly. While the term "ancestry" has recently been offered as a replacement, it is often used as a broad, ill-defined term that is used to encompass a number of concepts depending upon the user's current need (Bolnick 2008).

The final viewpoint is race is a necessary evil. Kennedy (1995) and Sauer (1992) have both taken this approach in their work as applied anthropologists in forensics. While forensic anthropologists are required to use an outdated, inaccurate paradigm, they recognize that race is not a biological concept. Sauer (1992) summarizes this approach by stating that skeletal identification of race has little bearing on the validity of the concept and that forensic anthropologists have an obligation to law enforcement to provide an accurate description of peer-perceived race.

This latter approach is the one most often seen in forensic anthropology. Forensic anthropologists work closely with law enforcement in medico-legal death investigations and a portion of the biological profile hinges upon the estimation of a racial category for the unknown individual. Forensic investigations proceed with an agenda: the identification of human remains. With this agenda, forensic anthropologists, especially those working in applied areas, are confined to the framework in which they work. They are charged with recognizing morphological and metric features that can be compared to a self-reported racial category on a missing persons form (Sauer 1992; Smay and Armelagos 2000). The forensic anthropologists are aware that biological race holds no scientific basis but, as Sauer (1992) points out, law enforcement officials have little interest in the academic pursuit of human variation when their job consists of something far more concrete and they face more immediate concerns in the identification process. They want results. These are results that forensic anthropologists appear to give, as they are accurate in estimating peer-reported race when presented with human remains (Sauer 1992; Hefner 2009; Konigsberg et al 2009).

Biological race does not exist but the addition of race, or ancestry as it has begun to be called, into the biological profile has resulted in the successful identification of unknown human remains (Sauer 1992; Hefner 2009; Konigsberg et al 2009). Forensic anthropologists must be assessing some form of variation between skeletons from population groups. Physical differences exist among ancestral groups that are patterned in consistent fashions. These differences can be attributed to geographic location and proximity of ancestral populations in a manner that allows for identification practices to be constructed around the concepts of ancestry instead of one of race. Forensic anthropologists cannot determine the color of a person's skin, hair, or eyes based upon skeletal attributes. What they can do – and continue to do – is to establish general ancestral population affinities, or ancestry estimations, from the hard tissue. It is also true that ancestry estimation only works on specific populations or in large groups, many of which cover broad cultural or geographic areas (i.e., Africa, Asian, South America, or Hispanic). Anthropologists recognize the complexities of human variation. Natural, discrete biological categories do not exist, yet these categories are used in a medico-legal context by law enforcement to identify the remains of unknown individuals. Excluding physical characteristics may hinder the process, yet the practice perpetuates the division of peoples, however unintentionally.

It is within the context of forensic anthropology that race is used in this study. As stated in the introduction, race is a social category built on discernible biological differences among populations that are culturally constructed and maintained for political and social purposes. Forensic anthropologists read features on the skeleton to estimate social categories based on superficial phenotypic expressions of complex patterns in genetic variation. Then, they aid in the identification of reported race in skeletal remains in medico-legal death investigations. The term "race" has been replaced with "ancestry" in many studies to avoid the connotations associated with race and racism in anthropology's origins. Using the term ancestry does not always solve this problem largely due to the fact that it has not been well defined in the literature and still suffers from many of the same connotations of the former vocabulary. Ancestry refers to a line of descent from one generation to another or many generations to the present and are typically depicted as broad categories (such as those discussed above) which are analogous to those used in earlier racial typography. Forensic anthropologists match physical indicators of ancestral populations to socially constructed racial categories. The application of race is based upon physical traits associated with an ancestral group.

For the purpose of this study, ancestry is used to estimate patterns of human variation, as the goal of a forensic anthropologist is not to determine the skin color but rather to estimate the individual's self- or peer-reported social race based on a number of osteological indicators reflected in the skeleton that share affinities for certain ancestral population groups that correlate with perceived ancestral groups. This subtle distinction is one that should be made. The use of these indicators in no way validates the scientific construction of biological race but rather seeks to better grasp environmental and genetic differences that do exist between populations whether or not they exist in a percentage that segregate them into a level of subspecies or beyond. In this study, two ancestry groups, Euro and African Americans, were chosen as sample groups for two major reasons. First is that these two groups are two historically prevalent in the United States. As of the 2010 census, they make up nearly 75% of reported race demographics in the country. Secondly, these groups are the most documented in skeletal populations available for study. These may lead to certain biases given the complexities of racial identity and the larger demographics of the United States. However, these two groups do make up a substantial percentage of the population for which methods are derived.

1.3 Nonmetric Traits in the Human Skull

Physical anthropologists traditionally study human variation in the human skeleton with the use of metric and nonmetric means (Rhine 1990). Metric analysis has been the primary source of quantifying human variation for centuries (Wescott and Moore-Jansen 2001; Spradley et al 2008; Konigsberg et al 2008) while nonmetric provides a more descriptive evaluation of the skeleton. Usually, studies involving nonmetric traits focus on the differences and similarities in morphological states of skeletal characteristics. Nonmetric evaluation of skeletal remains has been practiced since the early part of the twentieth century. Physical anthropologists have used various forms of nonmetric evaluation to assist in the estimation of age (Lovejoy et al 1985; Meindel et al 1985), sex (Phenice 1969; Walker 2008), and ancestry of unknown human remains.

For the purposes of this study, a nonmetric trait refers to any trait that is not quantitatively measured but instead described on a continuous, quasi-continuous, or discrete categorical scale. In recent research, these have been known interchangeably as morphoscopic traits to identify them in an osteological context. These traits are recorded as character states. They are most often recorded as ranked or scored based upon a visual inspection. For instance, they are present/absent or open/closed (also called discrete traits), or more/fewer than an expected value (Schwartz 1995). This can be the qualification of a bone shape, a feature, or a suture's shape (Hefner 2009). Less frequently (and more recently), they are assessed as degrees of variation, and recorded on a continuous or quasi-continuous scale, which offers a larger number of available categorical values and provides a better descriptive measure for variation within a specific trait.

Many of these traits were viewed as innocuous or even simply as biological anomalies by osteologists (Hauser and De Stefano 1989). For nearly two centuries, little thought was given to their meaning or distribution even in comparative anatomy. In the 1960s, nonmetric traits were used with increasing frequency to examine variation across populations on a wider scale with an interest in the presumed underlying genetic basis. Berry and Berry's 1967 paper on the frequency and distribution of nonmetric traits is largely regarded as a seminal study (Finnegan 1978; Schwartz 1995). The authors concluded that particular nonmetric traits reflected genotypes of a population. A number of researchers supported their findings in later studies (Ossenberg 1978; Wijsman and Neves 1986; Korey 1980) by linking genetic diversity in regional and continental populations using nonmetric variation trends as a marker of biological relatedness (Brasili 1999). Originally, the use of these traits has a very simple rationale: if morphology has a genetic basis then groups that are more morphologically similar to one another are more closely related. Traits are then used as proxy to establish genealogical relationships between global populations. Some researchers (Howells 1972; Jantz 1970; Rightmire 1972) questioned the reliability of using nonmetric traits and advocated using exclusively metric means while others (Carpenter 1976; Corruccini 1976; Ossenberg 1976; Trinkhaus 1978) found support for the theory that metric and nonmetric data were linked. Corruccini (1976) argued that nometric traits contributed significantly to exploring genealogical and genetic relationships in populations but his research, like others (Carpenter 1976; Ossenberg 1976), was often inconclusive.

By the early 1980s, nonmetrics were used with increasing frequency. The debate shifted focus from use of the traits to examining what the traits are actually measuring. Arguments came from uncertainty in earlier studies and many favored discontinuing use of such traits entirely or at least abandoning all previous work in favor of entirely new research (Cheverud et al, 1979). Instead, it is more productive to research the relationship between nonmetric traits and the knowledge they can provide physical anthropologists. Evaluating heritability and environmental influence of nonmetric traits has been of some interest to physical anthropologists, linking inheritance to nonmetrics (Carson 2006). The earlier arguments (Berry and Berry, 1967; Ossenberg, 1976) assumed that these traits were directly affected by genotype without much consideration or assessment into the degree of environmental influence.

Considering environmental factors as well as genetic ones, Trinkhaus (1978) concluded that "environmental forces are relatively important in controlling the expression of human nonmetric traits" (317). Factors such as climate, nutritional stress, and other factors affect the presence or absence of such non-metric traits. Additionally, it affects the symmetry of such traits, shown in the lack of bilateral expression in certain samples. Trinkhaus (1978) concluded these findings best support a model acknowledging some genetic control of nonmetric traits while allowing for modification from environmental factors.

1.4 Ancestry and Nonmetrics

The intersection of ancestry classification and nonmetric variation of the skull came early in the twentieth century. The modern use of nonmetric traits to assess variation in populations has roots in the work of E.A Hooton (1887-1954). Hooton, a physical anthropologist, is well known for his work in racial classification and phylogenetics (Birdsell 1987). His interest in nonmetrics spanned several decades (Hooton 1920; Hooton 1926; Brues 1990; Birdsell 1987). In his 1930 study 'The *Indians of Pecos Pueblo,'* Hooton makes the following assessment: "morphological features which can be observed and described but cannot be measured are probably of greater anthropological significance than diameters and indices" (Brues 1990; Hooton 1930).

Hooton worked extensively with the skeletal collection housed at the Harvard-affiliated Peabody Museum of Archaeology and Ethnology to catalogue variation in cranial nonmetrics. In the late 1930's, Hooton devised the first major undertaking in comparative anatomy of nonmetric traits across populations of the twentieth century (Birdsell 1987; Brues 1990). His creation was a ten-page form for recording nonmetric variation in the human skeleton with 102 observations; a number of these are categorical nonmetric traits with more than three degrees of variation while thirteen are recorded as present/absent traits (Brues 1990). Four pages detail cranial observations and another six are focused on the post-cranial skeleton. Though unpublished, his work eventually came to be known as the "Harvard List" and is still extensively cited today (Brues 1990; Birdsell 1987; Rhine 1990). It has also become the unacknowledged basis for later work in nonmetric ancestry estimation. While Hooton initially used nonmetric observations in his Madisonville study (1920) and his work on the Canary Islands (1925), the Harvard list was the first of its kind (Brues 1990). It was the first systematic approach to a standardization of methodology.

Hauser and De Stefano (1989) conducted an in-depth study of the frequency and variation of skeletal variation in Epigenetic Variants of the Human Skull. While this volume encompasses a vast amount of material and has a number of excellent drawings for reference, the authors' purpose was not to offer a definitive suite of traits to be used in a blind assessment for forensic purposes but to document frequency and character states of such traits. Additionally, this reference is increasingly difficult to purchase as the book has fallen out of print in recent years. One problem with this attempt – and many other attempts by future researchers – is the issue of standardization (Hefner 2009; Brues 1990; Walker 2005; Parr 2002). Subjectivity in the collection of data and the traits identified by researchers has been problematic with respect to further investigation on morphological variation. With most trait definitions and descriptions found in the literature minimal, there is difficulty in the replication of studies and few established standards. Another problem lies in inter-observer error, or the differences in interpretation by two or more individuals making observations of the same traits. Inter-observer error has been explored in earlier studies in nonmetrics (Hefner 2009; Giles 1995). Finnegan (1972; 1978) advocates solving this problem by using morphoscopic traits that can be labeled only as present or absent (discrete traits). Discarding traits that may fall outside this category may remove the ability to observe subtle variation over a continuum that is more significant than a dichotomist trait.

Nonmetric traits continue to be used as ancestry markers in the human skeleton. Yet ancestry does not explain all variation between individuals. In comparison to other species, the human skeleton is considered only mildly sexually dimorphic (Schwartz 1995; Brasili 1999). This has not been of detriment to the prolific, reliable use of morphological variation as an estimator of sex (Buikstra and Ubelaker 1994). Historically, the most reliable estimations of sex are done from the innominate, long bones, and skull. Typically, the cranial features of males are considered more robust than those of the comparatively more gracile females (Buikstra and Ubelaker 1994; Walker 2009). This is largely attributed to the change in hormones and growth during puberty when males of the species develop more stereotypically muscular frames and have a higher prevalence of testosterone than human females. The use of sexual markers, both metric and nonmetric, of the crania to estimate sex in an unknown individual is common for forensic anthropologists. While these traits have not been found to have any statistical significance between population groups nor have they been studied in any great detail, mentions in literature suggests the crania of African American, European American, Asian, and some Hispanic populations have differences in robusticity.

Forensic anthropologists use morphological characteristics of the crania to estimate an unknown individual's ancestry in a similar manner to which they would estimate sex. Using comparative morphology, traits are examined in relation to character states and typically taught in the "oral tradition" practiced as early as in Hooton's work (Brues 1990). This makes ancestry estimation dependent not exclusively upon scientific methodologies but instead largely on experience and subjective judgments that may vary between observers. In the United States specifically, human beings have typically been categorized into one of three discrete racial groups: black, white, and Asian (Sauer 1992; Brues 1990; Rhine 1990; Byers 2004). In North America, Black is used to describe African American populations with ancestry from regions of Africa (typically Western and Sub-Saharan regions) and Europe (Dupri 2008). In other countries, the term black could be associated with other ancestral populations and have other social connotations. White refers to those of European descent with minor other influences assumed. Even the Asian category carries the assumption of eastern Asia, specifically Japan, China, and Korea. With the influx of immigration in the 20th century, a fourth category, Hispanic, has recently been included (Spradley 2006). This category is one of the most undefined, problematic, and is yet under researched, as Hispanic is a linguistic category and can include anyone who identifies as Latino or comes from a Spanish-speaking cultural background.

In forensic anthropology, an individual's inclusion into a certain ancestral group is dependent upon a number of displayed morphological characteristics from the skeleton (Lundy 1986). Many times, nonmetric analysis is preferred to metric assessments, like those provided by the computer software FORDISC which specializes in estimation of ancestry using metric analysis, because it has the benefit of being faster, less expensive by requiring no delicate equipment, and there are numerous features available for analysis (Rhine 1990). Additionally, FORDISC is a difficult program to master. To use the program to its maximum potential, it requires specialized training to interpret results. The question soon becomes: what are "good" morphoscopic traits and how does one establish the criteria for them? (Schwartz 1995)

Several attempts have been made (Rhine 1990; Gill 1995; Hefner 2009) to establish the most reliable indicators of ancestry based upon nonmetric traits of the crania that correspond with population affinities and thus are commonly used by forensic anthropologists in ancestry estimation. In 1990, George W. Gill and Stanley Rhine published a collection of articles from Southwestern forensic anthropologists titled Skeletal Attribution of Race. Using a number of the traits outlined by these earlier authors and published in the Gill and Rhine volume, Rhine (1990) tested these in an effort to establish good criteria for future investigation. From this study came a number of the most frequently cited traits in modern studies and many of these are used in textbook training manuals for forensic anthropologists (Burns 2000; Byers 2004; Klepinger 2008). There are a number of problems with his study. Foremost among these were the size and distribution of his sample (n= 87). Sixty-eight were labeled as 'caucasoid' for the assessment and 15 of those were Hispanic. Only seven 'black' individuals were used in the study, two of which were casts of skulls. An additional 12 unaffiliated Native American skulls (a mixture of modern and historic) were also included in the sample. Context for those skulls were not given, nor where the criteria for the Caucasoid, black, or Native American skulls provided. With a sample this small and unrepresentative, it is difficult to assess the statistical power of the analysis. However, this article is most cited for forensic anthropological use, especially in training.

Hefner (2009) provides the most recent attempt at standardization of traits used in ancestry estimation. Narrowing his sample to twelve nonmetric traits, Hefner was able to develop clearly defined traits on a large sample from a much greater range of populations (nearly 600 individual skulls). These traits are among those most popular for use in forensic purposes. His efforts of standardization and the results of his study offer a better system for examination of nonmetrics. However, Hefner's study does not consider the possibility of secular change in nonmetric traits. Hefner's sample combines a modern skeletal sample with a historic one from the earliest part of the 20th century. Additionally, he does not distinguish between African and African American populations. For standardization of traits, it provides a well-rounded sample group. However, his study does not answer the question of how the distribution of these traits has changed over time.

The suite of traits most often used is not without a number of the issues stated above: lack of standardization in trait definition and differences in training among observers. Table 2.1 catalogues the most basic, classic view of what is considered typical for the ancestry categories most often used to describe American populations.

Table 1.1 Distribution of Nonmetric Cranial Traits Classically Associated with Ancestry Estimation in American Populations

Trait	Euro Americans	African Americans	American Indian / Asian
Nose Form	Narrow	Wide	Medium
Nasals Form	High	Low	Low
Interorbital Distance	Narrow	Wide	Medium
Nasal Spine	Large	Small	Medium
Nasal Sill	Sill	Guttering	Guttering
Alveolar Prognathism	None	Large	Medium
Orbitals	Rhomboid	Round	Rhomboid
Malars	Small, retreating	Small, horizontal	Flaring
Cranial form	Metopic suture	Post-bregmatic depression	n/a

Adapted from Gill, 1995 & Rhine, 1990

While some of these traits have been studied in depth, many of them remain locked into literature dating back to Hooton's Harvard List with little or no formal investigation and very few changes in trait distribution or definition reflect the passage of time or the distribution of skeletal populations.

1.5 Secular Change

Plasticity, or the ability of an individual organism to exhibit phenotypic change in reaction to environmental changes, is a phenomenon that has been well documented in the human skeleton since the work of Franz Boas in the 1940s. Secular change, or short term changes generally occurring across one or two generations, has been linked to everything from changes in average human stature to the differences documented in cranial vault shapes. While the reasons for these changes have been ascribed to dietary conditions, greater environmental changes, or genetic predisposition, the underlying causation may be something far more complex, indicating a confluence of interrelated factors (Sparks and Jantz 2003; Gravlee et al 2003).

Secular change has been a subject of interest in American populations since Boas' 1912 study of cranial plasticity in human populations as a response to the North American environment. Boas concluded that there was an increase in stature and cranial indices within American children born of immigrant parents. Initially, Boas' study served as a nail in the coffin of the typical racial typography of the day, concluding that racial affinities were not locked at birth as previous thought, and began interest in the affects of environment as well as genetics on the growth and morphology of humankind. Re-analysis of Boas' data using statistical means support his original findings while suggesting that this change is not always directly correlated exclusively with the new physical environment (Sparks and Jantz 2003; Gravlee et al 2003). While physical environment does have an effect, change in social and cultural environments may have more influence in secular trends seen in populations (Jantz and Logan 2010). While Boas attributed all change to the American environment, he did not specific what caused the changes. There is evidence that factors such as increased economic mobility or a change in social practices may have been a more influential cause than the physical. Though this does not change the import of Boas' findings, it does add another level of complexity to the issue.

Secular change has been documented in a number of regions on the skeleton in several population samples. The most well documented trends are seen in stature (Henneberg and van den Berg 1990; Meadows and Jantz 1995; Klepinger 2001; Wescott and Jantz 2005). For the skull, Angel (1982) noted a change in the cranial base height (the length taken on the skull between points porion to basion) among populations. This showed a marked increase in both skull size and cranial base height. This was attributed to nutritional improvements in periods of growth and maturation of the human skeleton (Angel 1982; Jantz 2001). Jantz (2001) examined secular change in the crania of North Americans by comparing metric data of black and whites. Jantz used the Terry Collection and Todd Collection as a historic nineteenth century sample and measurements from the Forensic Data Bank at the University of Tennessee at Knoxville for the modern sample. Of the fifteen standard measurements that were used, several show significant differences over time. Overall, the face became narrower in both ancestral groups and the cranial vault became higher. This is reflected in an increase in both basion to bregma height (the distance between basion, the mid-point on the anterior margin of the foramen magnum on the occipital bone, and bregma the point on the superior portion of the skull where the coronal suture intersects the sagittal suture), and in the occipital chord. The increase in nasion-basion height (the length between nasion, the intersection of the frontal and the two nasal bones, and basion) in both groups was considered an indicator of increased facial projection (Jantz 2001). Interestingly, the study showed more marked differences among whites over time than in the blacks.

In their 2000 article, Jantz and Meadows Jantz explore secular change in a comparison between 19th century and 20th century blacks and whites. Their data consisted of five craniofacial variables (glabella-occipital length, basion-bregma height, maximum cranial breadth, nasion-prosthion height, and bizygomatic breadth) and the analysis involved testing for changes in the geometric means of these measurements between skeletal populations. Jantz and Meadows Jantz (2000) report that overall, there is less change in the face than in the cranial vault. However, they also note that change in shape have been greater than those reported in cranial size. At this time much of the research into secular trends in humans has relied upon metric data. These forms of data provide standardization of measuring techniques long established for analysis.

Due to the unstandardized methodology of morphoscopic traits, they have largely been ignored in the secular literature as researchers favor methods that are easier and more conclusive for statistical analysis. Many of the current methods originated from osteological samples of populations in the 1800s. Much like revisions in stature formulas over the last decades to reflect trends in the heights of Americans, ancestry estimation methodology should reflect changes, if they exist, in nonmetric variation. If secular change is evident in morphological characteristics of the crania, then methodology should reflect the current populations in order to provide the most accurate forensic assessments for modern use. If secular trends are occurring quickly enough in nonmetrics that these changes are observable within the last century, it could lead to difficulty in assessing ancestry in certain individuals who do not fit the stereotypical mold for ancestral categories in the United States. At the worst, it could lead to misclassification of individuals, an outcome with disastrous results in the medico-legal context.

Conversely, when examining past populations, it is more conducive to provide methods that adequately address variation that can be seen among and between groups. With a standardized approach to morphological assessment, secular trends require further examination. As earlier studies suggest (Kouchi 2000; Wescott and Jantz 2005), shape changes more than size over time. While geometric morphometrics can catalogue this change, it may be possible to see a reflection in morphoscopic trait expression among populations. The current study seeks to explore this possibility in relation to traits associated with ancestry estimation for unknown human remains.

1.6 Research Questions

While the term "race" is considered outdated and inappropriate as a biological descriptor, forensic anthropologists still need to categorize recognizable skeletal variation to provide accurate, reliable assessments of ancestry to law enforcement officials seeking to match human remains to peer perceived ancestry on a missing persons form. With this agenda, forensic anthropologists assess trends in human variation to make estimations of ancestral affinities. These trends, while not supporting the concept of biological race, do have roots in the purported pattern of distribution in phenotypic expression of morphoscopic traits in the crania. It is the goal of the current study to analyze these patterns for consistency, standardization, and change over time. Previous studies have shown that there are measurable differences in the crania of modern Americans compared to that of early nineteenth-century cranial vault of American blacks and whites (Jantz 2001). This secular change is reflected in other parts of the skeleton as well: for example the increasing height of populations from the early 1900's (Meadows and Jantz 1995). A further assessment of nonmetric secular changes in American ancestry groups is an avenue of research as yet unexplored within current anthropology.

The current study builds from previous work done by Hefner (2009) to address the validity and need for standardization in nonmetric cranial variation. It builds from work done by Jantz (2001) and Jantz and Meadows Jantz (2000) on the changes in the skeleton attributed to secular change. It addresses three questions:

1) Do discernible morphological, nonmetric differences between two peer-perceived ancestry groups (Euro and African American) exist?

2) Are any nonmetric traits unique, alone or in combination, to either of these groups, to the exclusion of the other? Given the earlier assumptions that differences in trait distribution are a valid way to distinguish population groups from one another, trait distributions should reflect this in a manner that is easy to assess. If the current study aligns with earlier work, the traits more reflective of ancestry – which in this study are comprised of very specific global regions contributing to the population of the United States – should be associated with the mid-facial region of the crania.

And finally, 3) Have the distribution of nonmetric traits within ancestry groups exhibited any significant secular trends over time in the United States? If they have, does this change help or hinder their ability to help any future ability to differentiate between the two groups?

Table 1.2 examines the use of traits across literature most cited for ancestry estimation in forensic anthropology. The morphoscopic traits used in this study are listed in the left column. References are cited across the top row. These are listed chronologically to show a secular trend in trait usage as well. Some of the sources cited (Rhine 1990; Reichs 1998; Burns 1999; Byers 2010) are introductory texts for forensic anthropological technique and are those most commonly used in beginner instruction. Others represent early texts (El-Najjar 1978; Stewart 1979) that are not used with the same frequency. Specialized training manuals and texts (Bass 1995;

Klepinger 2006) were consulted to provide insight into the most generally accepted techniques for ancestry estimation. In many cases, traits were listed but not defined clearly. In the case of Hauser and de Stefano (1989), the reference material is excellent for trait definition but does not offer a definitive answer on trait usage for estimation techniques. While many traits are repeated in their usage, no two sources use the exact same standard for traits used in their analysis. Unlike in the assessment of sex or stature, there is no standard set, or suite, of traits used in investigations. Even within the context of a single trait, it is not uncommon to see different definitions or character states catalogued, especially in the case of nonmetric traits that have multiple states of expression. This is problematic for both students learning these techniques and also for anthropologists called upon to validate their findings in a medico-legal context.

Table 1.2 Nonmetric traits associated with ancestry estimation used in forensic identification techniques listed by source text. Sources are arranged chronologically.

Traits	Source										
	El – Najjar (1978)	Stewart (1979)	Hauser & de Stefano (1989)	Rhine (1990)	Bass (1995)	Gill (1995)	Reichs (1998)	Burns (1999)	Klepinger (2006)	Hefner (2009)	Byers (2010)
Metopic Suture			✓	✓					✓		
Nasal Overgrowth										✓	
Supranasal Suture			✓							✓	
Interorbital Breadth		✓		✓	✓	✓	✓		✓	✓	
Subnasal Margin (sill)	✓	✓		✓		✓	✓	✓		✓	✓
Orbital form	✓			✓		✓	✓		✓		✓
Nasal spine	✓			✓		✓	✓	✓	✓	✓	✓
Nasal bone contour		✓		✓		✓	✓	✓		✓	✓
Nasal aperture width	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Zygomatic projection	✓		✓	✓		✓	✓	✓	✓		✓
Zygomatic suture			✓	✓		✓	✓	✓		✓	
Malar tubercle				✓		✓			✓	✓	
Palatine Torus			✓								
Palatine Suture			✓	✓		✓	✓	✓		✓	
Prognathism	✓	✓		✓	✓	✓	✓		✓		✓
Chin Prominence				✓		✓					✓
Post-Bregmatic Cranial Depression				✓	✓			✓	✓	✓	✓
Inion Hook			✓	✓		✓			✓		
Coronal Ossicle			✓	✓		✓					
Sagittal Ossicle			✓	✓		✓					
Lambdoidal Ossicles			✓	✓		✓					✓
Inca Bone				✓							✓
Suture Complexity				✓		✓	✓	✓			✓
Cranially Robusticity	✓						✓		✓		✓

***Cranial robusticity was examined using four separate traits for this study: mastoid process, glabellar projection, suborbital margin, and occipital protuberance.**

CHAPTER 2
METHODS AND MATERIALS

2.1 Materials

To examine variation between groups, 27 morphoscopic cranial traits were collected from 441 four hundred and forty-one individuals. Traits were scored based on criteria defined by previous studies (Table 2.2). When definitions were unclear or *ad hoc*, they were assessed by earlier charts and a standardized definition was developed from informal ones. The study is almost exclusive to cranial morphological characteristics with the exception of mandibular chin shape. Dental attributes were excluded because large portions of available samples (specifically those from the Bass Donated Collection) were edentulous.

Of the traits used, all 27 have been associated with ancestry estimation and 23 of those exclusively so. While previous studies (Hefner 2003; Hefner 2009; Rhine 1990; Hauser and De Stefano 1989) have either not addressed the possibility of sexual dimorphism or indicated that there are no statistically significant differences between the sexes in ancestry ascribed traits, four sex-ascribed traits relating to cranial robusticity were included in the study. This was done to explore the suggestion that some differences in cranial robusticity may exist between ancestry groups (Byers 2010).

Because the study sample contained too few female crania, this study uses exclusively male crania from adults between 18 and 84 years old. Sexual dimorphism of the human crania has been well documented (Buikstra and Ubelaker 1994; Rogers 1999; Walker 2009). However, there is little evidence that nonmetric traits associated with ancestry show any difference by sex as of current research (Hauser and De Stefano 1989). However, it should be pointed out that these traits have largely been studied in non-contemporary populations and that often times a lack of female skeletons contribute to the samples used in studies.

The samples used for this study represent two ancestry groups: Euro Americans and African Americans. These two groups were chosen because they represent large portions of the United States population. Since the samples were comprised of individuals from the United States, ancestry groups were established to fit the vernacular. For African Americans, ancestry is most likely Sub-Saharan, Western, or South African with possible genetic admixture assumed from Europeans. In North America, individuals of a multi-racial or ancestral background are often considered black, which is a reflection upon the socioeconomic understanding of race. This is in part because of the "one drop" rule, a social convention that often assumes ancestral affinity into one group based upon physical appearance. For example, an individual is assumed to be black instead of being multiracial based largely upon skin color. For the Euro Americans, ancestry of the individuals is European with possible minor genetic influences. Social convention refers to those of European ancestry as white, though the spectrum is just as broad as those considered black. Membership to each group was peer-reported and recorded before or around the time of death.

Modern crania were sampled from The William M. Bass Donated Skeletal Collection and skeletal material housed at Louisiana State University FACES Laboratory. The two samples are from contemporary time periods (individuals were born exclusively within the 20th century) and they were combined in the study. The Robert J. Terry Anatomical Skeletal Collection, comprised of individuals from the 19th and early 20th century, provided the historic sample. Distributions of the sample can be found in Table 2.1.

Table 2.1 Sample (n) distributions from each of the comparative examples used in the study.

Collection	African Americans	Euro Americans	Totals
Bass	44	146	190
LSU	34	-	34
Terry	109	108	217
	187	254	441

WM Bass Donated Collection

Established in 1981 by Dr. William M Bass, the WM Bass Donated Skeletal Collection (commonly referred to as the Bass Collection) was created as an avenue for research into skeletal biology. As of May 2011, the collection is composed of nearly 900 adult individuals, most of which were born after 1930 and died between 1980 and the present. The collection is heavily based in both Euro American individuals and in males many of those whom are in the older age demographic.

While the earliest donations were largely granted from medical examiners, the collection is mostly comprised of donations from families of a decedent or a direct donation from the individual. Those earliest donations were localized from the Tennessee area but the program now receives donations across the country, eliminating some of the geographic bias. The Bass Donated Collection continues to receive donations and represents the current living population of the United States. A total of 185 individuals were sampled from the Bass collection representing two groups based upon peer-identified ancestry groupings: Euro American (n=146) and African American (n=44). Ancestry was reported in all cases by the donating family.

Louisiana State University FACES Laboratory

To supplement the modern sample, an additional 34 African American skulls were added to the study from the Louisiana State University Forensic Anthropology and Computer Enhancement Services laboratory (LSU FACES lab) in Baton Rouge, Louisiana. The LSU FACES Lab is an education and research facility located on the premises at the LSU anthropology department. Mary H. Manhein, director of the laboratory, founded the FACES lab with government research grants to further inquiry into the identification of unidentified remains in the Southern United States. The lab is heavily involved in forensic investigation for both law enforcement and a variety of mass disasters, such as the aftermath of Hurricane Katrina. While the Lab does house skeletal material available for study, it is not a formal collection. Most material is kept in forensic context or for research purposes. Demographics for the facility were not available but at the time of research, there were approximately 100 individuals housed in the laboratory. All skulls used for analysis were of known ancestry and sex though in some cases age was estimated.

Robert J. Terry Collection

To provide a historic reference sample, The Robert J. Terry Collection was used. The Robert J. Terry Collection was established in 1910 after Dr. Robert Terry developed a standardized protocol for collecting and documenting skeletal remains (Hunt and Albanese 2005). The early skeletons were procured from medical school cadavers. They represented those of a lower socio-economic status in the St. Louis and Missouri areas as individuals who remained unclaimed at local morgues. Instead of being buried at the taxpayers' expense, they were donated to the medical school and utilized for the osteological collection.

In 1941, Terry retired, leaving his position as anatomy instructor to Dr. Mildred Trotter, which included the responsibility of maintaining the osteological collection. She expanded the collection until her retirement in 1967 and was responsible for broadening the demographics by focusing on the curation of younger individuals and women. These later parts of the collection represent middle and upper class incomes as well as lower (Hunt and Albanese 2005).

The RJT collection is currently housed at the Smithsonian Museum of Natural History in Washington D.C. It is comprised of 1728 individuals; age, sex, ancestry, causes of death and pathological skeletal conditions are catalogued. The RJT Collection was chosen due to availability and because it is one of the largest and most extensively studied skeletal collections in the United States (Hunt and Albanese 2005). For this project, a total of 217 skulls were used from the Terry collection: 109 European Americans and 108 of African Americans.

2.2 Osteological Methods

Traits

Twenty-seven morphoscopic traits were recorded for this study and taken from several areas of the crania including the midfacial region, the vault, and the mandible. Traits were selected based on several criteria. Given the use of nonmetric data for assessment of modern forensic and archeological human remains of interest, additional consideration was given to traits commonly used for classification and identification of unknown individuals. Inter-observer error was a factor contributing to selection; traits were chosen to reduce possibility of error and based upon previous studies (Hefner 2009; Rhine 1990; Carson 2006). Definition and assessment criteria for each trait was taken from earlier, foundational studies and supplemented by recent research advocating the use of traits for forensic purposes. Eleven traits were taken from Hefner's 2009 study using new standardization techniques and were evaluated used his criteria and visual aids. These are referenced in the text as such. Some commonly used morphoscopic traits lack well-documented description or analysis in earlier literature even if they are commonly used as predictors for ancestry estimation. In these cases, definitions were compiled from brief mentions in early texts and from traditionally non-standardized training.

In the total 27 traits used, 10 were discrete and 17 were categorical. Ten discrete features were scored on the basis of being present or absent on the skull. In the case of bilateral traits, each side was scored separately. For the sake of consistency and standardization only, left side, when available, was used for analysis. While Trinkhaus (1978) established that many discrete morphoscopic traits do express asymmetry, the traits used in this analysis were effectively minimally asymmetrical (Hauser and de Stefano 1989). The additional 17 features were scored as categorical character states based upon prominence, robusticity, shape, or size. The technique for assessing each trait was taken from earlier studies, reaching from Krogman (1955) to Rogers (1999), Komar and Buikstra (2008), and Hefner (2009). Table 1.1 illustrates the traditional distribution of variables classically associated with ancestry estimation.

Source material for each definition is cited in Table 2.2 and Table 2.3 and specific references for standardized definitions are cited in the text. The traits are organized by their location on the skull or, in the case of traits associated with sex estimation, grouped separately.

Nonmetric Traits of the Midfacial/Facial Region

1. **Metopic suture**
   This is also known as the metopic trace or partial metopism. It is an incomplete persistence of the metopic suture that is immediately superior to nasion. This differs from the supranasal suture in that it is generally non-complex in that it forms a non-oscillating line (Rhine 1990; Hauser and de Stefano 1989). This trait was scored 0 for absent and 1 for present.

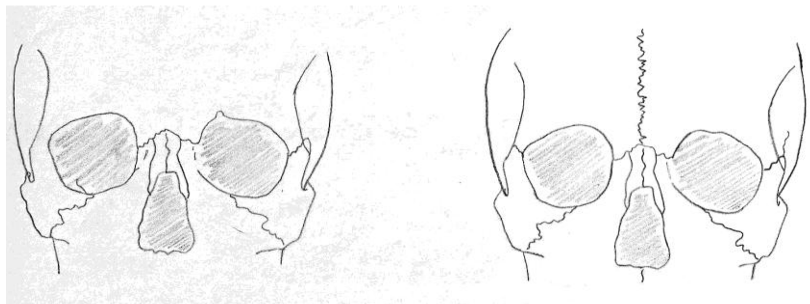


Figure 1 Character states of the metopic suture: 0) absent and 1) present. Adapted from Buikstra and Ubelaker (1994).

2. Nasal overgrowth

A discrete trait characterized by any amount of anterior projection of the lateral portion of the nasal bones beyond the maxillae. Can be viewed in lateral profile and does not include any anterior bulging of the nasal bones. Hefner (2009) suggests running a finger along the borders of the maxilla and nasal bones at nasale inferious to assess this trait. This trait was scored 0 for absent and 1 for present.

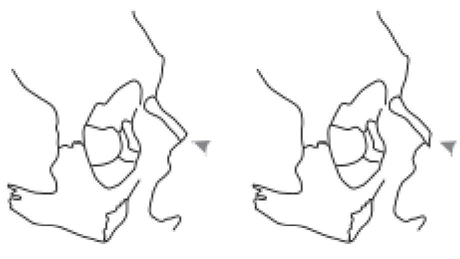


Figure 2. Nasal Overgrowth.0) Absent and 1) Present. Reproduced from Hefner (2009)

3. Supranasal Suture

Evidence of a secondary complex cranial suture located on the anterior region of the frontal bone just superior to nasion. While it may superficially resemble the nasal portion of a metopic suture trace, the supranasal suture (or sutura supranasalis) appears at the glabella as a complex of interlocking bony spicules. This differs from metopic suture trace in that the metopic suture generally forms a single, non-oscillating line. For the purpose of this study, the supransal suture was scored based on criteria and definitions developed in an earlier study by Hefner (2009). It was scored as follows: 0 – completed obliterated, 1 – open (unfused), or 2 – closed but visible.

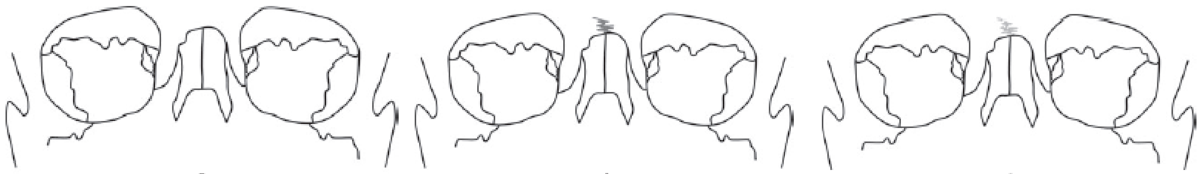


Figure 3. Character states for supranasal suture. Reproduced from Hefner (2009)

4. **Interorbital breadth**
   Interorbital beadth refers to the distance in the medial orbits – dacryon to dacryon. This is a nonmetric trait that can also be measured metrically using sliding calipers. When assessing this trait nonmetrically, it is scored relative to the size of facial morphology (Hefner 2009; Klepinger 2006; Rhine 1990). Scored as: 1 – narrow, 2 – intermediate, or 3 – broad.

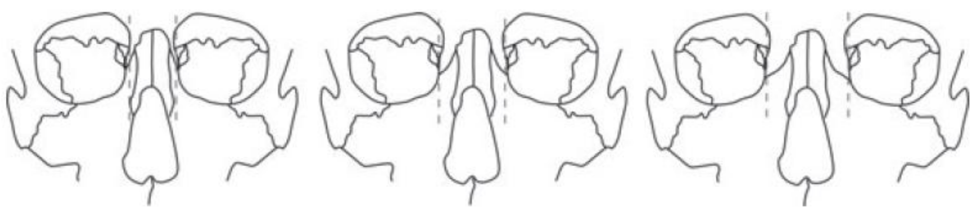


Figure 4. Character states for Interorbital Breadth. 1) Narrow, 2) Intermediate, and 3) Wide. Reproduced from Hefner (2009)

5. **Subnasal margin (sill)**
   This is the the most inferior portion of the nasal aperture, which, when combined with the lateral alae, constitutes the transition from nasal floor to the vertical portion of the maxillae, superior to the anterior dentition Subnasal margin an assessment of the shape of the inferior border of the nasal aperture. In cases where bilateral asymmetry did occur, the left side was used (Hefner 2009).
   This trait is scored as follows: 1 - an inferior sloping of the nasal floor that begins within the nasal cavity and terminates on the vertical surface of the maxilla, producing a smooth transition. The morphology is distinct from regarding the more posterior origin and the greater slope of the aperture; 2- sloping of the nasal aperture beginning more anteriorly than in 1 and with more angulation at the exit of the nasal opening; 3 - the transition from nasal floor to the vertical maxilla is not sloping, nor is there an intervening projection, or sill. Generally, this morphology is a right angle, although a more blunted form may be observed; 4 - any superior incline of the anterior nasal floor, creating a weak (but present) vertical ridge of bone that traverses the inferior nasal

border (partial nasal sill); and 5 - a pronounced ridge (nasal sill) obstructing the nasal floor-to-maxilla transition.

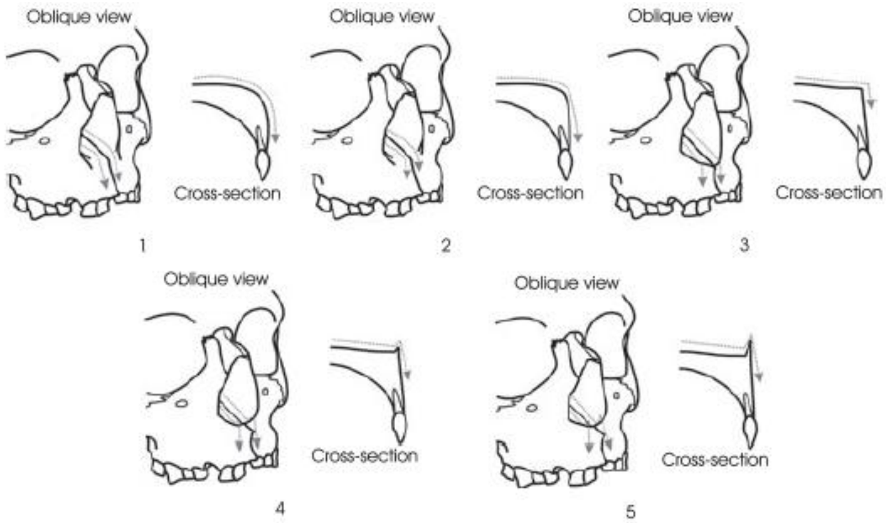


Figure 5. Character states of the Inferior Nasal Sill. Reproduced from Hefner (2009)

6. Orbital form

Orbital form was defined as the shape and slope of the eye orbits in relation to the midline portion of the facial skeleton (Rhine 1990; Reichs 1987; Klepinger 2006).

This was scored as follows: 1 – orbits are square in shape shaped but exhibit no sloping in the inferior lateral maxillary portions; 2 – orbits are square in shape and exhibit a downward sloping at the inferior lateral maxillary edge; 3 – orbits are rectangular, elongated horizontally and exhibit sloping at the inferior lateral maxillary edge; 4 – orbits are rectangular, elongated horizontally and show no signs of sloping; and 5 – orbits are rounded.

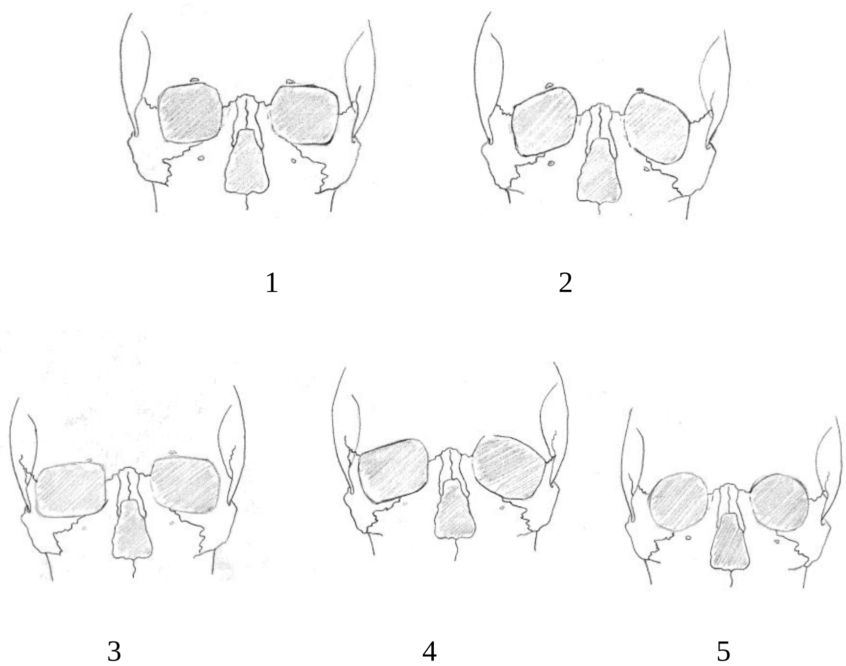


Figure 6. Character States of orbital form. 1) square, 2) square and sloped, 3) rectangular, 4) rectangular and sloped, and 5) rounded. Adapted from Buikstra and Ubelaker (1994).

7. **Anterior inferior nasal spine**

Nasal spin morphology was assessed by examining the crania in profile. The extent to which the nasal spine projects beyond the inferior portion of the nasal aperture was assessed. Criteria for progressive scoring of this trait were taken from Hefner (2009): 1 – slight: minimal to no projection beyond the inferior portion of the nasal aperture, 2 – moderate: some projection, or 3 – marked: pronounced projection of the nasal spine beyond the inferior nasal aperture.

It should be noted that this area is very fragile. In cases where damage does exist (from trauma or postmortem damage), it is impossible to assess this feature and thus all cases where portions of the nasal aperture were damaged or missing were not used in analysis.

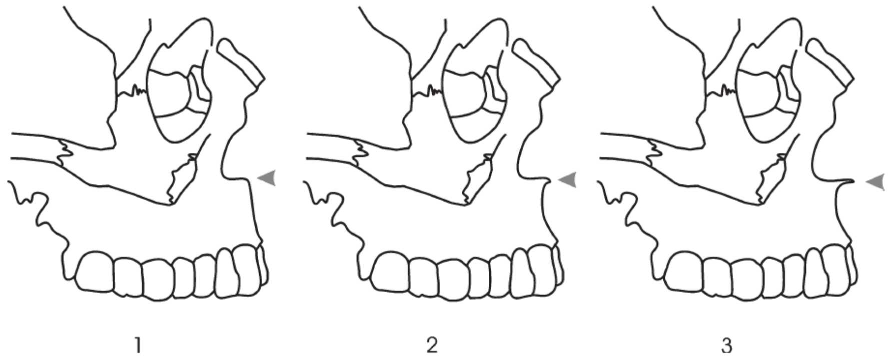


Figure 7. Character states for the inferior anterior nasal spine: 1) slight, 2) moderate, and 3) pronounced. Reproduced from Hefner (2009)

8. Nasal bone contour

The contour of the nasal bone was taken at approximately one cm below nasion. (Rhine 1990; Brues 1990; Hefner 2009).

Scored as: 0 – Low and rounded, 1 – oval contour with elongated, high, and rounded walls, 2 – plateau shaped with steep lateral walls and a roughly flat surface on the superior margin, 3 - steep-sided laterial walls and a narrow surface resembling a semi-triangular plateau, or 4 – triangular cross-section (generally referred to as pinched), lacking any plateau.

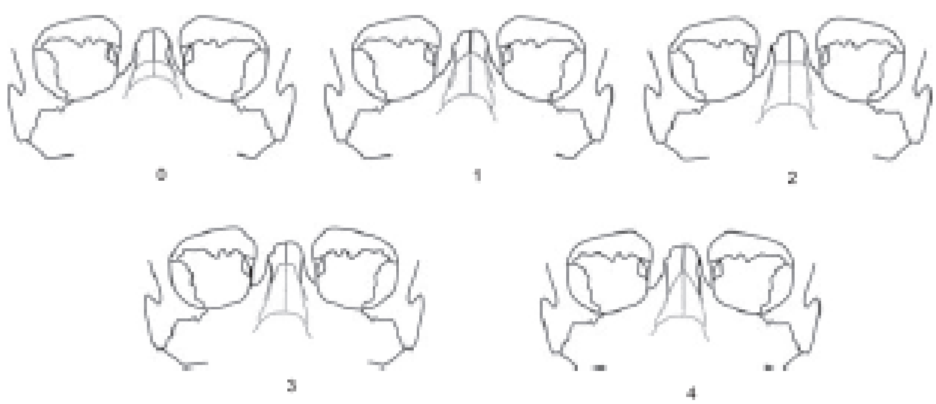


Figure 8 Character states of nasal bone contour. Adapted from Hefner (2009).

9. Nasal aperture width

This is the width of the nasal aperture at its most wide point and is assessed relative to the mid-facial region of the skeleton as a whole. The overall shape of the opening is taken into consideration (Hefner 2009; Klepinger 2006; Rhine 1990).

Scoring of this trait was assessed as: 1 – narrow and forming an isosceles triangle, 2 – medium, or 3 – broad and forming an equilateral triangle.

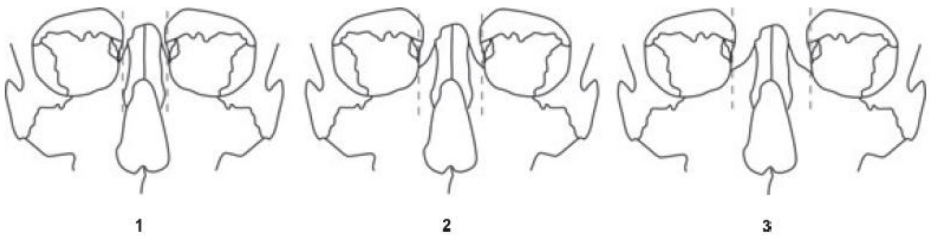


Figure 9. Character states of nasal aperture width: 1) narrow, 2) intermediate, and 3) wide. Reproduced from Hefner (2009).

10. Zygomatic Projection

The zygomatic, also called the malar or cheek bone, is a paired bone in the human face. For this, a line is dropped from the middle of the upper margin of the orbit to the middle of the lower margin that produces an angle with the Frankfort plane (Rhine 1990; Reichs 1987).

This trait is scored 1 – the angle produced that is more than 90 degrees retreating , 2 – an angle of 90 degrees is vertical, or 3- an angle of less than 90 degrees is projecting.

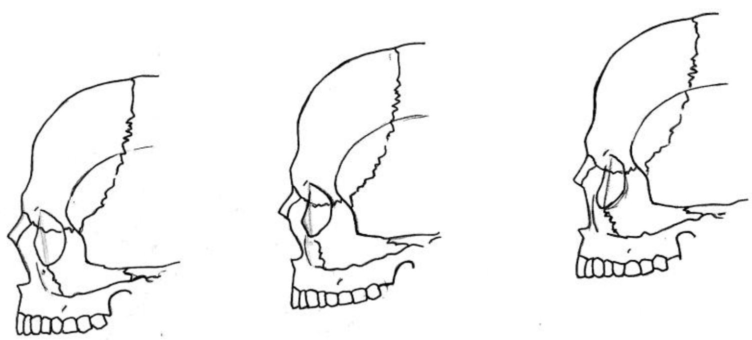


Figure 10. Character states of zygomatic projection. 1) retreating, 2) vertical, and 3) proecting. Adapted from Buikstra and Ubelaker (1994).

11. Zygomaxillary suture (shape)

The zygomaxillary suture is located between the maxilla and the zygomatic bone. The course of the suture is observed anteriorly and in cases of asymmetry, the left side is scored. Assessment of this trait is based primarily upon the point of greatest lateral projection of the suture and also the number of major angles present in the course of the suture (Hefner 2009).

To score this trait: 0 – where the suture has no major angles and the point of most lateral projection is at the most inferior margin of the zygomatics. 1 – a suture with one angle and greatest lateral projection near the midline, 2 – a suture with two or more angles (which gives the suture a jagged or s-shaped appearance) and where the greatest lateral projection is variable, dependent upon the shape. When the suture was too obliterated to score (labeled as 3 in the drawing), it was left blank.

Figure 11. Character states of zygomaxillary suture shape. Reproduced from Hefner (2009).

12. Malar tubercle

This trait was defined and scored following Hefner (2009) and Hauser and De Stefano (1989). This is a caudally projecting tubercle located on the inferior margin of the maxilla and zygomatic bone in the region of the zygomatic suture. Placing a transparent ruler at the intersection of the zygomatic suture and the inferiore margin of the malar to the deepest point on the curvature of the maxilla, the assessment is made based on the protrusion beyond the ruler's edge. The malar tubercle can be present on the zygomatic, the maxilla, or along the zygomatic suture.

Scoring of this trait follows: 0 – no projection of bone, 1 – a trace tubercle below the ruler's edge (roughly 2 mm or less), 2 – a medium protrusion below the ruler's edge (roughly 2-4 mm), 3 – a pronounced tubercle below the rule's edge (roughly 4 mm or more).

Figure 12. Character states of the malar tubercle. Reproduced from Hefner (2009).

Nonmetric Traits of the Palate and Chin

13. Palatine torus

The palantine torus is a thickening of bone forming a central ridge or ridges located on the horizontal plate of the palatine and palatine process of the maxilla (Rhine 1990; Brasili et. al. 1999). This trait was scored 0 for absent and 1 for present.

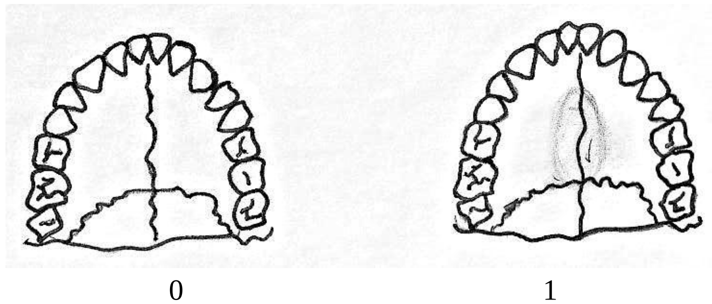


Figure 13. Character states of the palatine torus: 0) absent and 1) indicating the area where one would be seen. Adapted from Buikstra and Ubelaker (1994).

14. Transverse palatine suture

Traditional definitions for this trait categorize it's trajectory as bulging or straight. However, new studies have pointed out more diverse in expression than originally assessed. It is a highly variable trait with certain themes that are often seen. To score, the medial one-half of the region of the palatine suture should be examined. If the suture is asymmetrical (where the left and right sides of the suture do not meet at the midline), this trait should be scored by the overall theme of the suture. If the suture is obliterated, then it cannot be assessed (Hefner 2009).

For scoring: 0 – the suture crosses the palate perpendicular to the median palatine suture with no anterior/posterior deviations, 1 – the suture crosses the palate perpendicular to the median palatine suture but near this point, a significant anterior deviation, referred to in the literature as "bulging" occurs. This should be scored even if the two halves do not meet at the midline, 2 – the suture crosses the palate but deviates both anteriorly and posteriorly. This is referred to as an m-shaped suture and should be scored even if the right and left sides of the suture do not meet at the midline. 3 – the suture crosses at the palate perpendicular to the median palatine suture but deviates significantly posteriorly (bulging).

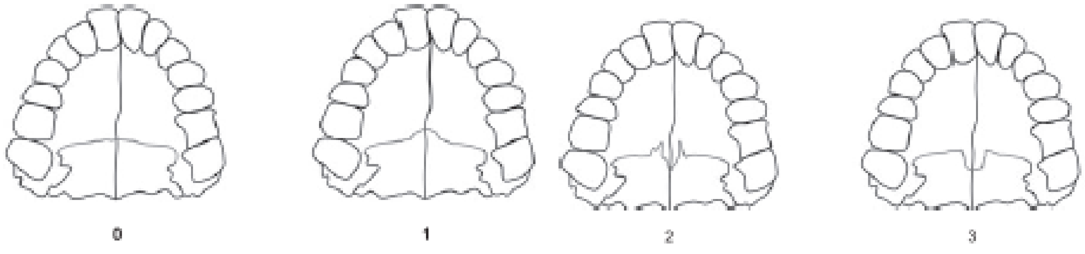
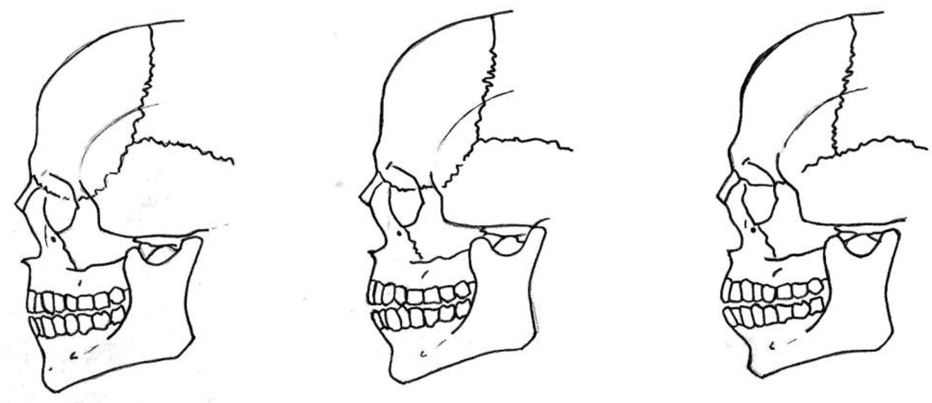


Figure 14. Character states of the palatine suture shape. Reproduced from Hefner (2009).

15. Prognathism

Alveolar prognathism refers to the positional relationship of the maxilla and mandible that is a forward projection of those regions of the face with an increased length of each. This trait was scored by degree of forward projection and was assessed with the skull positioned in lateral profile (Rhine 1990; Gill 1995; Reichs 1998; Klepinger 2006) This trait is scored: 0- none meaning no visible projection, 1 – moderate or slight forward projection of the mandible and maxilla , 2 – pronounced projection . In cases where there has been alveolar absorption or massive edentulation, this trait cannot be scored.

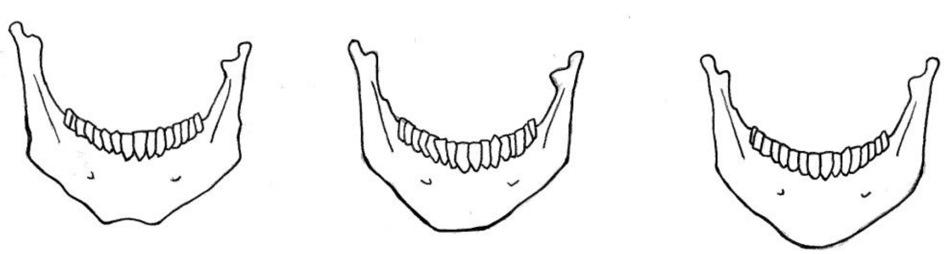


0 1 2

Figure 15. Character states of alveolar prognathism: 0) none, 1) slight, and 2) pronounced. Adapted from Buikstra and Ubelaker (1994).

16. Chin shape

Chin shape refers to the frontal projection of the mandible when held in profile. The chin is examined relative to the face and alveolar area (Rhine 1990; Klepinger 2006). This trait is scored: 1- prominent forward projection and often exhibiting a bilobate eminence; 2- vertical projection and bluntly shaped; or 3- recessive and without any projection and shape is rounded and without a prominent point.



1 2 3

Figure 16. Character states of the chin: 1) bilobate, 1) blunt, and 2) rounded. Adapted from Buikstra and Ubelaker (1994).

Nonmetric Traits of the Cranial Vault

17. Post-bregmatic depression

This refers to the presence of a small depression at the top of the crania, located immediately posterior to bregma on the cross section of the sagittal and coronal sutures. This can best be viewed when the crania is in lateral profile (Hefner 2009). This trait was scored 0 for absent and 1 for present.

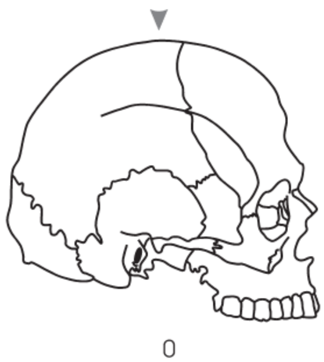


Figure 17. Character states of Post Bregmatic Cranial Depression: 0) absent and 1) present. Figure reproduced from Hefner (2009)

18. Inion hook

This is an inferiorly located projection found on the external occipital protuberance (Rhine 1990; Klepinger 2006). This trait was scored 0 for absent and 1 for present.

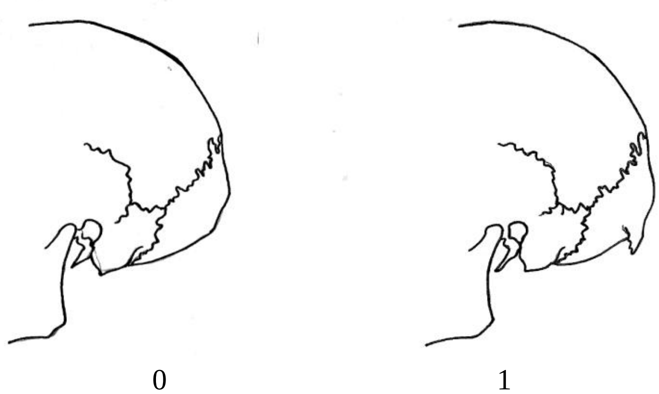


Figure 18. Character states of the inion hook: 0) absent and 1) present. Adapted from Ubelaker and Buikstra (1994).

19. Coronal ossicle

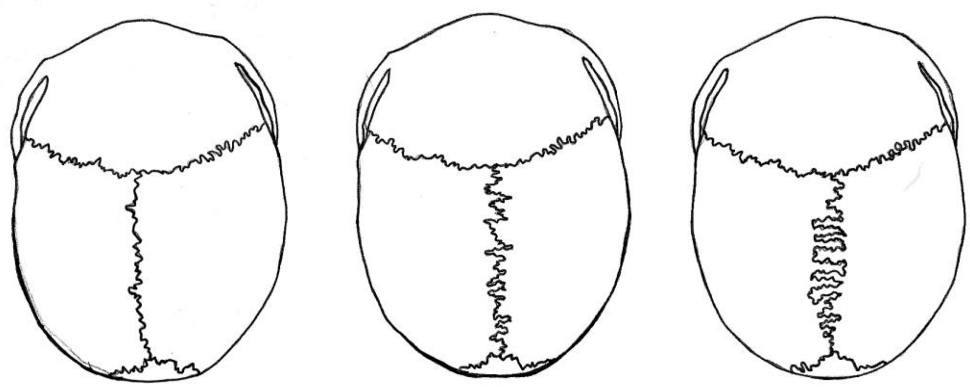
A small island or islands of bone at the coronal suture formed by the complexities of sutural coursing. These are located at the coronal suture, largely found near the superior portion of the crania (Hauser and de Stefano 1989; Gill 1995). This trait was scored 0 for absent and 1 for present.

20. Sagittal Ossicle

A small island or islands of bone at the sagittal suture formed by the complexities of sutural coursing. These are located on the sagittal suture and also referred to as wormian bones (Hauser and de Stefano 1989; Gill 1995). This trait was scored 0 for absent and 1 for present.

21. Lamboidal ossicles

A small island or islands of bone at the occipital suture formed by the complexities of sutural coursing. These are often located near lambda or near the temporal and also referred to in the literature as wormian bones (Hauser and de Stefano 1989; Gill 1995). This trait was scored 0 for absent and 1 for present.

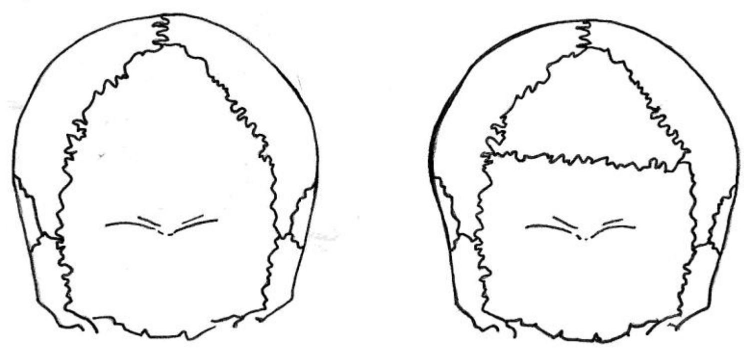


19 20 21

Figures 19 -21. Character states of the 19) coronal ossicles, 20) sagittal ossicles, and 21) lamboidal ossicles. Adapted from Buikstra and Ubelaker (1994).

22. Inca bone

The presence of a small island of bone located at the cranial landmark lambda at the course of the lambdoidal suture. This differs from typical wormian bones in the location of the extra bone piece and also due to the larger size of the bone (Hauser and de Stefano 1989; Gill 1995). This trait was scored 0 for absent and 1 for present.



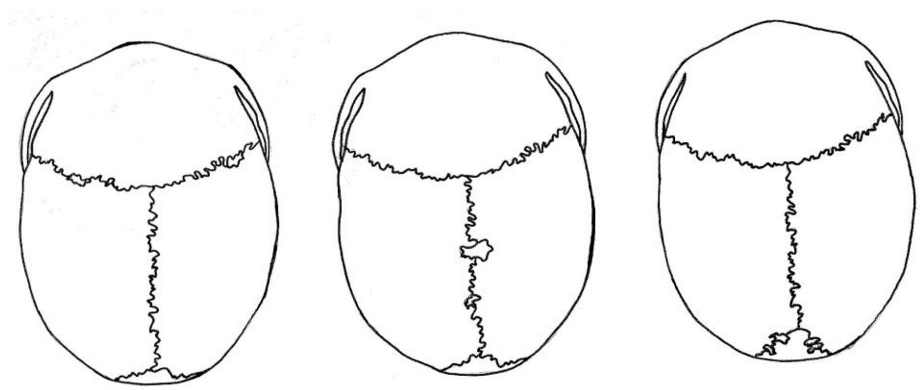
0 1

Figure 22. Character states of the inca bone: 0) absent and 1) present. Adapted from Buikstra and Ubelaker (1994).

23. Suture complexity

The complexity of the major sutures is scored based upon their deviation from a hypothetical straight line. While there are a number of major cranial sutures, if there were discrepancies between sutures, priority was given to the saggital suture (Rhine 1990; Klepinger 2006).

These were scored as: 1 – simple, 2 – medium, or 3 – complex.



1 2 3

Figure 23. Character states of sutural complexity: 1) simple, 2) intermediate, and 3) complex. Adapted from Buikstra and Ubelaker (1994).

Nonmetric Traits Associated with Sex Estimation

24. Occipital protuberance

Located at the middle of the occipital squama, the occipital protuberance is a prominence on the outer surface of the bone projecting outwards (Roger 1999; Bass 1994). Assessment is based upon the degree of projection at the back of the skull.

This is scored: 1 – the external surface of the occipital is smooth with no bony projections visible from when the lateral profile of the occipital is viewed; to 5 – a massive nuchal crest that projects considerable distance from the bone and forms a well defined ledge or hook of bone.

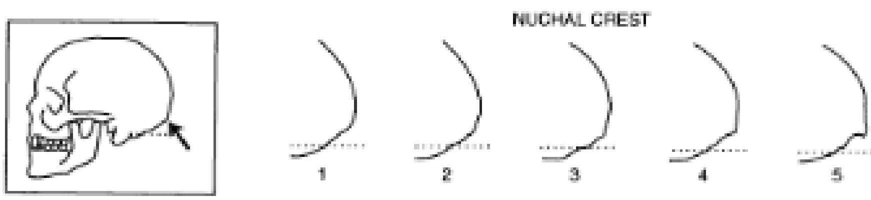


Figure 24. Character states of occipital protuberance. Reproduced from Buikstra and Ubelaker (1994).

25. Mastoid process

The mastoid process is a conical prominence projecting inferiorly from the underside of the mastoid portion of the temporal bone. It is located just behind the external auditory meatus. This trait should be examined using overall volume and rugosity of the mastoid process instead of the length (Rogers 1999; Bass 1994).

This is scored from 1 – a very small mastoid process that projects only a small distance below the inferior margins of the external auditory meatus and digastric groove to 5 – a mastoid process that is several times the size of the external auditory meatus in terms of lengths and widths.

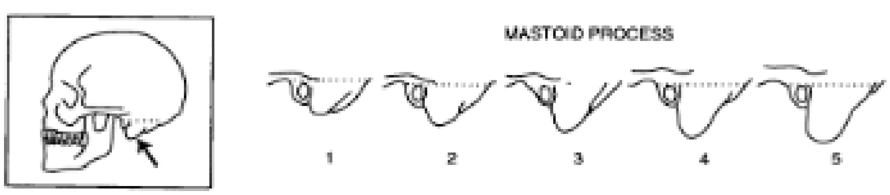


Figure 25. Character states of mastoid process. Reproduced from Buikstra and Ubelaker (1994).

26. Glabella projection

Also called the supraorbital ridge, or the brow ridge, the glabellar projection is the bony ridge located above the eye sockets. This trait is best assessed in a lateral view though some obvious approximations can be made in the anterior view. Examine the profile of the glabella in relation to the supra-orbital area of the skull, specifically the anterior projection of the frontal area (Rogers 1999).

This is scored from 1 – contour of the frontal is smooth with little to no projection in the glabellar areas to 5 – the glabella and the supra-orbital ridge are massive and from a rounded loaf shaped projection.

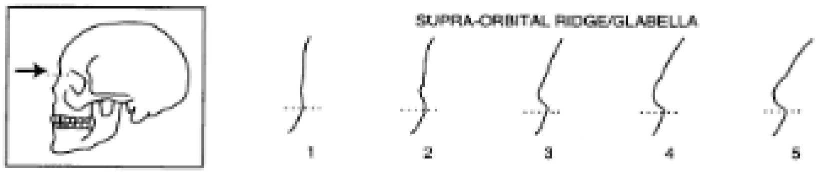


Figure 26. Character states of occipital protuberance. Reproduced from Buikstra and Ubelaker (1994).

27. **Suborbital margin**

Located at the inferior portion of the superior portion of the eye orbit, the suborbital margin refers to the portion of bone that makes up the upper edge of the eye orbit. This trait is scored by placing an index finger against the superior margin of the orbit in the area lateral to the supra-orbital foramen.

This is scored from 1 - the minimal expression (a thin border with the sharpness equivalent to the edge of a dull knife) to 5 – a rounded margin with a curvature that approximates that of a pencil.

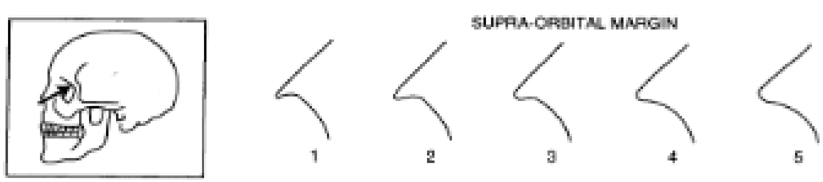


Figure 27. Character states of suborbital margin. Reproduced from Buikstra and Ubelaker (1994).

2.3 Statistical Methods

Nonmetric scores of the crania were recorded for each individual. Frequency tables for each trait and score within trait were calculated to examine differences between the two ancestral groups and between the historic and modern samples. Chi-square analyses were employed to determine whether or not these differences in distribution were considered significant (with significance at $p < 0.05$). Those with significant results were then examined to see what trends, if any, were present between ancestry groups for each trait. Chi-squared analysis (with significance $p < 0.05$) was also used to evaluate significant change between the historic and modern samples. All statistical analyses were conducted in PASW Statistics 18.

Logistic regression was used to predict which of the morphoscopic variables were collectively most accurate in estimating ancestry and to assess the traits that provide the best prediction of ancestry for American blacks and whites, logistic regression was utilized. Specifically, backward stepwise regression was used to determine the variations that were best predictors of ancestry estimation. Backwards elimination begins with all candidate variables included in the analysis and tests them one by one for statistical significance ($p < 0.05$) and then excludes any that are not significant. The backwards stepwise approach continues until the variables have been optimized for maximum accuracy in the final model. It also removes variables that are highly correlated with others or redundant in the low level of their statistical significance. This is often used when there are a large number of potential variables but no underlying theory to which to base the model selection. In this analysis, the use of backwards stepwise is optimal given the large number of morphoscopic traits under evaluation.

General linear models, the family of statistical analyses that includes logistic regression, determine the impact of multiple independent variables presented, either simultaneously or in a stepwise manner, to predict group membership of dependent variable categories. Generally, the dependent or response variable is dichotomous, such as presence/absence or success/failure. In this study, logistic regression allows for the allocation of an unknown individual to a set of *a* *priori* defined groups, American blacks or whites, and generates posterior probabilities of group membership. The predictive accuracy of the regression is determined by examination of the classification table that shows correct and incorrect assignments of individuals into the groups. Logistic regression is used to find the relationship between the independent variables and the natural logarithm, or the "logit function" of the odds of occurrence and predicts the likelihood of an occurrence, measured in probability. The resulting formula is in the form of

$$\text{Log-odds} = A + B_1(X_1) + B_2(X_2) + B_3(X_3)\ldots$$

where A is the constant, B values are the coefficients and X values are the morphological scores for variables.

This method is similar to discriminant function analysis. While discriminant analysis is also used to predict group membership with only two groups, it can only be used with continuous independent variables or, more rarely, with dichotomous categorical variables (data scored 0 or 1). Thus, in instances where the independent variables are poly-categorical, such as with the score of many variables used for nonmetric estimation, logistic regression is preferred because it requires fewer assumptions and is more statistically robust than a discriminant analysis.

To further examine the role of secular change, logistic regression was used to create two additional formulas: one for the historic sample and another for the modern sample. For this analysis, variables chosen from the combined sample equation were entered into the logistic equation simultaneously, referred to as the block entry method, in order to create an equation that would be tailored exclusively to each group. Accuracy rates for each equation within groups were formulated for each of the two. From there, accuracy was tested between groups, as the formula devised from the modern sample tested with a historic sample and vice versa to test for changing accuracy rates.

CHAPTER 3. RESULTS

In this chapter, the results of the analyses explained in the previous section will be discussed. In order to examine the utility of the 27 traits selected for study of ancestry estimation, they must be examined for certain criteria. First, the frequency distributions of these traits were assessed. While the majority of traits used in the study are referenced in earlier literature, the evidence for their distribution is largely anecdotal and untested on a large sample size. Secondly, secular change is addressed in the form of chi-square tests conducted between the Terry Collection skeletal material and the combined Bass Donated Collection and LSU skeletal material. Third, logistic regression statistics were used to establish the best nonmetric predictors of ancestry for each group and then to further explore secular change.

3.1 Descriptive Statistics

Frequency statistics of nonmetric trait scores were tabulated for each of the variables in both American blacks and whites. From these tables, comparisons between ancestry groups can be made. Additional comparisons can be seen between the modern collection when compared to the historic in the frequency tables presented. In the modern sample, African American data from the Bass Donated Collection and the LSU collection were pooled into a single source. The value and the usefulness of these traits are dependent upon the ability to distinguish one population group from another. Without that usefulness, they have no use for forensic application. It is imperative to keep this in mind when estimating ancestry with morphoscopics. From these tables, comparisons in the two ancestral categories can be made with a chi-square test. These results are shown in Table 3.1. Significance between groups was noted at $p < 0.05$ level for all analyses.

Table 3.1 Chi-Square analyses compared frequencies of nonmetric traits in American blacks and Whites. The modern and historic samples were combined for analysis.

Nonmetric Trait	Value	Df	Sig.
1. Metopic suture	.861	1	.354
2. Nasal overgrowth	13.368	1	**.000**
3. Supranasal suture	14.765	2	**.001**
4. Interorbital breadth	146.346	4	**.000**
5. Subnasal margin (sill)	193.887	4	**.000**
6. Orbital Form	93.877	4	**.000**
7. Anterior interior nasal spine	27.617	2	**.000**
8. Nasal bone contour	125.145	4	**.000**
9. Nasal aperature width	164.681	3	**.000**
10. Zygomatic projection	36.068	2	**.000**
11. Zygomaxillary suture shape	12.828	2	**.002**
12. Prognathism	114.386	2	**.000**
13. Chin Shape	23.201	5	**.000**
14. Malar Tubercle	2.875	3	.411
15. Palatine Torus	.420	1	.615
16. Transverse Palatine Suture	7.962	3	.093
17. Post-bregmatic cranial depression	3.312	1	.180
18. Inion hook	1.616	1	.261
19. Coronal ossicle	3.450	2	.178
20. Sagittal ossicle	0.000	1	1.000
21. Lambdoidal ossicle	.369	1	.514
22. Inca bone	.943	1	.332
23. Suture complexity	1.658	2	.436
24. Occipital protuberance	7.848	4	.097
25. Mastoid process	32.062	4	**.000**
26. Glabella projection	27.717	4	**.000**
27. Suborbital margin	7.356	5	.195

Mid-Facial Nonmetric Traits

The nonmetric traits associated with the appearance and shape of the midfacial region of the skull are presented in Table 3.2. This region is largely associated with measures of the nose and face in metric analysis and is analogous to the same in nonmetric traits. Of the fifteen craniofacial traits used in the study, ten were significant at the $p < 0.05$ level. These were: nasal overgrowth, supranasal suture, interorbital breadth, subnasal margin, anterior inferior nasal spine, nasal bone contour, nasal aperture width, orbital form, zygomaxillary suture shape, and zygomatic projection. While these did show significance, the variation within the traits does exceed expected frequencies from early studies (Rhine 1990).

Table 3.2 Midfacial Region. ***Frequency of nonmetric traits used in the study. All traits were associated with ancestry estimation in forensic anthropology. Trait frequencies are separated between Modern and Historic population groups. For each sample, Euro refers to Euro American and African refers to African American.***

Nonmetric Trait	**Historic**				**Modern**			
	Euro		**African**		**Euro**		**African**	
	n =110	**%**	**n =107**	**%**	**n =138**	**%**	**n=79**	**%**
1. Metopic Suture								
Present	6	5.5	8	7.5	5	3.6	4	5.1
Absent	104	94.5	99	92.5	133	96.4	75	94.9
	Euro		**African**		**Euro**		**African**	
	n =94	**%**	**n =93**	**%**	**n =129**	**%**	**n=65**	**%**
2. Nasal Overgrowth								
Present	29	30.9	16	17.2	45	34.9	10	15.5
Absent	65	69.1	77	82.8	84	65.1	55	84.6
	Euro		**African**		**Euro**		**African**	
	n =107	**%**	**n =106**	**%**	**n =137**	**%**	**n=77**	**%**
3. Supranasal Suture								
Completely obliterated	50	46.7	64	60.4	54	39.4	34	44.2
Open	31	29.0	18	17.0	54	39.4	15	19.5
Closed but visible	26	24.3	24	22.6	29	21.2	28	36.4
	Euro		**African**		**Euro**		**African**	
	n =109	**%**	**n =105**	**%**	**n =138**	**%**	**n=75**	**%**
4.Interorbital Breadth								
Narrow	81	73.0	28	26.7	100	72.5	19	25.3
Intermediate	26	24.7	28	26.7	33	23.9	15	20.0
Broad	2	2.3	49	46.7	5	3.6	41	54.7
	Euro		**African**		**Euro**		**African**	
	n =109	**%**	**n =107**	**%**	**n =138**	**%**	**n=72**	**%**
5.Nasal Sill								
Guttering	2	1.8	37	34.6	5	3.6	28	28.9
Incipient guttering	6	5.5	36	33.6	8	5.8	18	25.0
Straight	14	12.8	20	18.7	21	15.2	10	13.9
Partial sill	27	24.8	11	10.3	35	24.6	13	18.1
Sill	60	55.0	3	2.8	70	50.7	3	4.2

Nonmetric Trait	Historic				Modern			
	Euro		African		Euro		African	
	n =109	%	n =107	%	n =136	%	n=	%
6. Orbital Shape								
Square/Not Sloped	14	12.8	13	12.1	7	5.1	10	14.5
Squared/Sloped	44	40.4	12	11.2	94	69.1	10	14.5
Rectangular/Sloped	25	22.9	20	18.7	28	20.6	33	47.8
Rectangular/Non-Sloped	23	21.1	56	52.3	5	3.7	13	48.8
Rounded	3	2.8	6	5.6	2	1.5	3	4.3
	Euro		African		Euro		African	
	n =102	%	n =107	%	n =133	%	n=72	%
7. Nasal Spine								
Slight	24	23.5	55	51.4	39	29.3	38	52.8
Moderate	30	29.4	29	27.1	62	46.6	20	27.8
Marked	48	47.1	23	21.5	32	24.1	14	19.4
	Euro		African		Euro		African	
	n =106	%	n =100	%	n =133	%	n=70	%
8. Nasal Contour								
Low/rounded	1	.9	21	21.0	0	0	17	24.3
Oval	12	11.3	41	41.0	11	8.3	14	20.0
Plateau	4	3.8	8	8.0	12	9.0	13	18.6
Steep Sided	34	32.1	17	17.0	50	37.6	17	24.3
Triangular	55	51.9	13	13.0	60	45.1	9	12.9
	Euro		African		Euro		African	
	n =109	%	n =107	%	n =138	%	n=72	%
9. Nasal Aperture Width								
Narrow	74	67.3	17	16.9	95	68.8	8	11.1
Medium	26	23.6	27	25.2	35	25.4	23	31.9
Broad	9	8.2	63	58.9	8	5.8	41	56.9
	Euro		African		Euro		African	
	n =107	%	n =106	%	n =138	%	n=73	%
10. Zygoma Shape								
Slender	68	63.6	47	44.3	96	69.6	31	43.1
Vertical	29	27.1	27	25.5	33	23.9	23	31.9
Projecting	10	9.3	32	30.2	9	6.5	18	25.0
	Euro		African		Euro		African	
	n =106	%	n =103	%	n =130	%	n=73	%
11. Zygomatic Suture								
Smooth	56	60.9	64	62.1	42	30.4	40	54.8
Angled	46	41.8	34	33.0	66	47.8	49.4	37.0
S-shaped	4	3.6	5	4.9	22	15.9	27	8.2

Nonmetric Trait	Historic				Modern			
	Euro		African		Euro		African	
	n =107	%	n =107	%	n =137	%	n=70	%
12. Malar Tubercle								
0	79	73.8	75	70.1	58	42.3	31	44.3
1	18	16.8	18	16.8	44	32.1	18	25.7
2	9	8.4	11	10.3	34	24.8	20	38.6
3	1	.9	3	2.8	1	.7	1	1.4

Nasal Overgrowth.

Nasal overgrowth, a trait associated with Asian populations, has a very low frequency in both ancestry groups that matches Hefner's (2009) results. However, it is seen twice as frequently in Euro American than African Americans.

Supranasal Suture.

Supranasal suture has a higher incidence of being scored as completely obliterated (0) in the African American group when compared to the Euro American sample where the trait is more often seen as open (1) or closed but visible (2).

Zyogmatic Projection.

Zygomatic projection shows a trend that is contrary to traditional ancestry estimation. Retreating zygoma are prominently within the Euro American group. However, the African American sample shows far more variation across the three categories: slender (1), vertical (2), and projecting (3).

Zygomaxillary Suture Shape.

With the shape of the zygomaxillary suture, the African American sample showed a higher likelihood of being smooth (1) rather than either angled (2) or s-shaped (3). Euro

Americans show greater variability in the formation of the suture with a slightly higher tendency of being angled in the modern sample.

Interorbital Breadth.

Interorbital breadth followed a basic pattern for the European group with over 70% of the sample scoring as narrow (1) and less than 5% as broad (3). The African American group showed a much higher degree of variation across the three possible assessments and though over 50% were scored as broad, which is the supposed typical category for the ancestry group, the other half were scored across the other two categories.

Orbital Shape.

The shape and configuration of the eye orbits follow an interesting pattern between groups. The Euro American sample exhibited a high degree of lateral sloping but some variation in shape between square and rectangular. They were mostly frequently assessed as being sloped and square. The African American sample was primarily rectangular in shape but could be either sloped or non-sloped. Both groups showed only a rare occurrence in rounded orbits, typically considered an indicator of Asian ancestry. It was also rare to see squared and unsloped orbits in either group.

Nasal Aperture Width.

The same trend is repeated in the analysis of nasal aperture width, showing that the traditional definitions for European ancestry shown in other studies matches while the African American group displays a higher degree of variation that previously reported.

Nasal Bone Contour.

The use of nasal bone contour is often cited in the literature as a reliable indicator of ancestry; this is confirmed by the current analysis. The European sample has a very low incidence of low/rounded nasal bones (0), a trait considered African American and tends to score most frequently as triangular (4) or steep sided (3). It should be noted that both ancestry groups do score within the accepted Asian/Native American designation of plateau (2). Additionally, the African American sample again shows a much higher level of variation than the Euro American though it still follows the pattern illustrated in other studies.

Inferior Nasal Margin.

The inferior nasal margin was significant across groups as well. Over 75% of the Euro American sample scored according to the traditional typological assessment for ancestry of a partial (4) or full nasal sill (5) while between 55-68% of the African American sample fell within the range of guttering (1) or incipient guttering (2). This is consistent with previously defined standards for both groups.

Nasal Spine.

A trait often associated with nasal margin, the nasal spine, exhibited significant frequency distribution as well. Variation across ancestry groups does exist with a much higher frequency of marked (3) nasal spines appearing in the European ancestry sample when compared to the high frequency of slight (1) among the African American sample. However, both groups frequently fall into the moderate (2) category (27-46%), making this trait difficult to be used independently with any success.

Frequency distributions of metopic suture and malar tubercle were all found to be nonsignificant. Metopic suture, in particular, is of interest because it has commonly been correlated as a trait found in individuals of European ancestry. However, it was found to be largely absent in both ancestry groups with only infrequent appearance in either. Malar tubercle size was found to be nonsignificant across groups as well.

Nonmetric Traits of the Palate and Chin

Two alveolar features, prognathism and chin shape, were also found to have distinct differences between groups as well (Table 3.2).

Prognathism.

The African American sample exhibited significant frequency of pronounced (2) prognathism while the European sample exhibited none (0). In cases where slight (2) prognathism was scored, the percentages were more likely to be among the African American sample as well.

Chin Shape.

Chin shape frequencies were found to be significantly different between groups but do not fit the patterns indicated by previous studies. The most often reported chins shape among the European sample was blunt (2) while African Americans were scored as either a blunt (2) or rounded and often retreating (3) shape. Traditional ancestry estimation techniques have previously indicated that European groups will have a bilobate (1) chin, though analysis indicated this was rarely seen in either group.

Table 3.3 presents the frequency distribution of palatine tori and the transverse palatine suture, neither of which exhibited significance in distribution. The frequency of palatine tori present in either ancestry group is rare with no variation between groups. Traditionally, palatine suture shape has been used as an indicator of ancestry. However, this study shows no significance in shape among groups, contrary to previous studies indicating that a bulging shape (1) is an indicator for African American and Europeans while no deviation (0) is most common among American Indian groups. This study indicates there is a high degree of variation between both groups with neither showing any general tendency towards shape.

Table 3.3 Palatine Region. Frequency distribution of morphoscopic traits of the palatine region and chin shape among population groups. All traits were associated with ancestry estimation in forensic anthropology. Trait frequencies are separated between Modern and Historic population groups. For each sample, Euro refers to Euro American and African refers to African American.

Nonmetric Trait	**Historic**				**Modern**			
	Euro		**African**		**Euro**		**African**	
	n =81	**%**	**n =95**	**%**	**n =58**	**%**	**n=54**	**%**
13. Prognathism								
None	66	81.5	23	24.2	58	84.1	11	20.4
Slight	10	12.3	20	21.1	9	13.0	22	40.7
Pronounced	5	6.2	52	54.7	2	2.9	21	38.9
	Euro		**African**		**Euro**		**African**	
	n =91	**%**	**n =101**	**%**	**n =119**	**%**	**n=64**	**%**
14. Chin Shape								
Bilobate	9	9.9	5	5.0	23	19.3	2	3.1
Blunt	53	58.2	47	46.5	73	61.3	37	57.8
Rounded	29	31.9	49	48.5	23	19.3	25	39.1
	Euro		**African**		**Euro**		**African**	
	n =109	**%**	**n= 106**	**%**	**n =135**	**%**	**n=73**	**%**
15. Palatine Torus								
Present	8	7.3	4	3.8	17	12.6	11	15.1
Absent	101	91.8	102	96.2	118	87.4	62	84.9
	Euro		**African**		**Euro**		**African**	
	n =100	**%**	**n =100**	**%**	**n =128**	**%**	**n=66**	**%**
16.Transverse Palatine Suture								
No deviation	35	35.0	24	20.0	37	29.4	12	18.2
Bulging	41	41.0	53	53.0	60	47.6	39	59.1
m-shaped	15	15.0	17	17.0	21	16.7	14	21.2
Bulging posterior	9	9.0	6	6.0	8	6.3	1	1.5

Nonmetric Traits of the Cranial Vault

Ancestry markers associated with the cranial vault were also scored in the samples (Table 3.3). None of these were found to be significant at the $p < 0.05$ level. The presence of an inion hook has been previously linked with individuals of European ancestry yet it appears very rarely within either ancestry group. On the other hand, post-bregmatic cranial depression has been commonly cited as a trait exclusive to those of African ancestry yet it shows no significant distribution across the African American samples used in this study. It also appears with similar infrequently across the European samples as well. Given that Hefner (2009) showed a significant distribution in his combined African and African American samples, this may be a trait more frequently found among African populations with a significant increase and not among those of African American descent.

Table 3.4 Cranial Vault. Frequency distributions of morphoscopic traits of the cranial vault associated with ancestry estimation in two skeletal populations. All traits were associated with ancestry estimation in forensic anthropology. Trait frequencies are separated between Modern and Historic population groups. For each sample, Euro refers to Euro American and African refers to African American.

Nonmetric Trait	Historic				Modern			
	Euro		African		Euro		African	
17. Post-begmatic depression	n =109	%	n =105	%	n =136	%	n= 76	%
Present	12	10.9	18	16.8	7	5.1	10	13.2
Absent	97	88.2	87	81.3	129	94.9	66	86.8
	Euro		African		Euro		African	
18. Inion Hook	n =110	%	n =106	%	n =138	%	n=81	%
Present	11	10.0	7	6.6	18	13.1	8	9.9
Absent	99	90.0	99	93.4	119	86.9	73	90.1

Nonmetric Trait	Historic				Modern			
	Euro		**African**		**Euro**		**African**	
	n =110	**%**	**n =107**	**%**	**n =125**	**%**	**n=64**	**%**
19. Coronal Ossicle								
Present	3	3.2	12	11.2	7	5.6	2	3.0
Absent	92	96.8	95	88.8	118	94.4	64	97.0
	Euro		**African**		**Euro**		**African**	
	n =110	**%**	**n=87**	**%**	**n =110**	**%**	**n=60**	**%**
20. Sagittal Ossicle								
Present	5	5.5	5	5.7	6	5.5	3	5.0
Absent	86	94.5	82	94.3	104	94.5	57	95.0
	Euro		**African**		**Euro**		**African**	
	n =92	**%**	**n =97**	**%**	**n =120**	**%**	**n=**	**%**
21. Lambdoidal Ossicle								
Present	26	23.6	30	30.9	38	31.7		
Absent	66	60.0	67	69.1	82	68.3		
	Euro		**African**		**Euro**		**African**	
	n =107	**%**	**n =102**	**%**	**n =129**	**%**	**n=68**	**%**
22. Inca Bone								
Present	8	7.5	11	10.8	8	6.2	5	7.4
Absent	99	92.5	91	89.2	121	93.8	63	92.6
	Euro		**African**		**Euro**		**African**	
	n =91	**%**	**n =94**	**%**	**n =114**	**%**	**n=61**	**%**
23. Suture Complexity								
Simple	72	79.1	49	52.1	27	23.7	20	32.8
Medium	12	13.2	17	18.1	33	28.9	13	21.3
Complex	7	7.7	28	29.8	54	47.4	28	45.9

Nonmetric Traits Associated with Sex Estimation

While most of the discussion linking ancestry and nonmetric estimators of sex on the skull are anecdotal, a chi-square analysis was conducted to explore what relationship, if any, exists between the two. Table 3.4 reports the frequency distributions of four nonmetric indicators of sex between the two ancestry groups: occipital protuberance, mastoid process length, glabellar projection, and suborbital margin. Of the four, mastoid process length and glabellar projection were significant in the analysis though all four did fall well within the ranges for scores associated with adult males. The African American sample appears to show more robusticity in the mastoid process when compared to the European American sample. In contrast, glabellar projection is significantly more robust in the Americans of European descent when compared to those of African descent. While significant, these differences do not act as good predictors of ancestry due to the subtle nature of the difference.

Table 3.5 Sex Estimation. Frequency distributions of nonmetric traits associated with sex estimation. Trait frequencies are separated between Modern and Historic population groups. For each sample, Euro refers to Euro American and African refers to African American.

Nonmetric Trait	Historic				Modern			
	Euro		**African**		**Euro**		**African**	
	n =109	**%**	**n= 103**	**%**	**n =137**	**%**	**n=80**	**%**
24. Occipital Pro.								
1	1	.9	8	7.8	8	5.8	1	1.3
2	8	7.3	9	8.7	8	5.8	13	16.3
3	27	24.8	27	26.2	29	21.2	22	27.5
4	39	35.8	35	34.0	44	32.1	24	30.0
5	34	31.2	24	23.3	48	55.0	20	25.0
	Euro		**African**		**Euro**		**African**	
	n =110	**%**	**n= 105**	**%**	**n =138**	**%**	**n=80**	**%**
25. Mastoid Process								
1	7	6.4	4	3.8	5	3.6	2	2.5
2	23	20.9	7	6.7	22	15.9	8	10.0
3	21	19.1	17	16.2	43	31.2	13	16.3
4	36	32.7	30	28.6	46	33.3	29	36.3
5	23	20.9	47	44.8	22	15.9	28	25.0
	Euro		**African**		**Euro**		**African**	
	n =110	**%**	**n =106**	**%**	**n =138**	**%**	**n=77**	**%**
26. Glabella Projection								
1	0	0	2	1.9	0	0	2	2.6
2	2	1.8	6	5.7	14	10.1	9	11.7
3	7	6.4	23	21.7	18	13.0	20	26.0
4	37	33.6	43	40.6	59	42.8	30	39.0
5	64	58.2	32	30.2	47	34.1	16	20.8

Nonmetric Trait	Historic				Modern			
	Euro		**African**		**Euro**		**African**	
	n =110	**%**	**n =106**	**%**	**n =137**	**%**	**n=79**	**%**
27. Suborbital Margin								
1	1	.9	0	0	1	.7	2	2.5
2	1	.9	4	3.8	7	5.1	8	10.1
3	13	11.8	25	23.6	31	22.6	19	24.1
4	17	15.5	27	25.5	48	35.0	20	25.3
5	78	70.9	50	47.2	50	36.5	30	38.0

3.2 Exploring Secular Change

To evaluate secular change in two common ancestry groups in the United States, a chi square analysis was conducted comparing the Historic sample (composed of skulls from Terry Collection) to the Modern sample (comprised of skulls from the Bass Donated Collection and those from the LSU FACES lab). The scores for European American males are presented in Table 3.5 while the scores for African American males are in Table 3.6. Significant results indicate that change in the shape or size of each trait has occurred over time.

Table 3.6 Chi Square Analysis for cranial nonmetric traits associated with sex and ancestry estimation for males of European descent. Comparison between Historic and Modern samples.

Nonmetric Trait	Value	Df	Sig.
1. Metopic suture	0.484	1	0.486
2. Nasal overgrowth	.339	1	0.528
3. Supranasal suture	2.896	2	0.235
4. Interorbital breadth	3.218	4	0.522
5. Subnasal margin (sill)	1.155	4	0.885
6. Orbital Form	29.777	4	**0.000**
7. Anterior interior nasal spine	14.057	2	**0.001**
8. Nasal bone contour	5.326	4	0.255
9. Nasal aperture width	1.859	3	0.602
10. Zygomatic projection	1.188	2	0.552
11. Zygomaxillary suture shape	15.755	2	**0.000**
12. Prognathism	.900	2	0.638
13. Chin Shape	6.372	2	**0.041**
14. Malar Tubercle	25.352	3	**0.000**
15. Palatine Torus	1.810	1	0.179
16. Transverse Palatine Suture	1.720	3	0.632
17. Post-bregmatic cranial depression	2.907	1	0.088
18. Inion hook	.580	1	0.446
19. Coronal ossicle	1.150	2	0.563
20. Sagittal ossicle	.000	1	0.990
21. Lambdoidal ossicle	.287	1	0.592
22. Inca bone	.150	1	0.797
23. Suture complexity	5.966	2	0.051
24. Occipital protuberance	5.086	4	0.279
25. Mastoid process	6.076	4	0.194
26. Glabella projection	18.561	3	**0.000**
27. Suborbital margin	32.207	5	**0.000**

Sig. at $p < 0.05$

Table 3.7 Chi Square Analysis for cranial nonmetrics associated with sex and ancestry estimation for males of African American descent. Comparison between Historic and Modern Samples.

Nonmetric Trait	Value	Df	Sig.
1. Metopic suture	.439	1	0.508
2. Nasal overgrowth	.092	1	0.761
3. Supranasal suture	5.302	2	0.071
4. Interorbital breadth	1.404	2	0.496
5. Subnasal margin (sill)	4.058	4	0.398
6. Orbital Form	24.496	4	**0.000**
7. Anterior interior nasal spine	.110	2	0.946
8. Nasal bone contour	10.630	4	**0.031**
9. Nasal aperature width	1.425	2	0.490
10. Zygomatic projection	1.067	2	0.587
11. Zygomaxillary suture shape	1.358	2	0.507
12. Prognathism	6.722	2	**0.035**
13. Chin Shape	2.067	2	0.356
14. Malar Tubercle	14.789	3	**0.002**
15. Palatine Torus	7.183	1	**0.007**
16. Transverse Palatine Suture	3.161	3	0.367
17. Post-bregmatic cranial depression	.535	1	0.464
18. Inion hook	.667	1	0.414
19. Coronal ossicle	2.915	1	0.088
20. Sagittal ossicle	.039	1	0.844
21. Lambdoidal ossicle	.524	1	0.469
22. Inca bone	.563	1	0.453
23. Suture complexity	5.966	2	0.051
24. Occipital protuberance	6.305	4	0.177
25. Mastoid process	2.769	4	0.597
26. Glabella projection	3.962	4	0.411
27. Suborbital margin	6.390	4	.0172

Sig. at $p < 0.05$

Among Americans of European descent, orbital form, anterior inferior nasal spine, zygomaxillary suture, chin shape, malar tubercle, glabellar projection, and suborbital margin were significant (Table 3.6). For the African American sample, significant differences were found in orbital form, prognathism, malar tubercle, and the palatine torus (Table 3.7).

3.3 Logistic Regression Model

All nonmetric variables exhibiting significance for predicting ancestry were included in the regression analysis. Since missing variable data for each individual of the sample could greatly affect the sample size and power of the tests, the historic and modern samples were pooled for analysis. Through the process of likelihood ratio backwards stepwise regression, the least significant variables were eliminated from the predictors chosen for the final logistic regression equation (Table 3.8).

Twelve variables previously established as significant were used in the analysis (Table 3.1). The most statistically significant nonmetric traits for assessing ancestry from those used in the study were nasal bone contour, nasal sill, nasal width, degree of prognathism, and chin shape (Table 3.8). The formula for ancestry determination of the crania using logistic regression is

Log-odds = A + B_1(Nasal Bone Contour) + B_2 (Nasal Sill) + B_3(Nasal Width) + B_4(Prognathism) + B_5(Chin Shape).

This formula has an accuracy rate for American males of African American and European descent at 93.1% with 93.6% for European Americans and 92.6% for African Americans. Table 3.8 shows the variables chosen for the final logistic regression model; it also lists the constant and coefficient for each trait used. Typically, it would be ideal to cross-validate the results of the analyses to see how the resulting equation would generalize an independent data set by performing the analyses on one subset and validating the analysis on another subset. PASW does not offer an analysis for cross-validation of logistic regression. Cross-validation technique was not done in this analyses; this may indicate a slight bias in the classification rates. Further discussion on the use of the equation can be found in the following chapter.

Table 3.8 Variables in the Final Logistic Regression Model. This includes all individuals in the combined groups (historic and modern) sample. This table shows the final five variables chosen in the logistic regression equation. They are listed with their coefficients (B values) as well as the constant (A) for the equation.

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 7[a]	SILL			22.106	4	.000	
	SILL(1)	5.191	1.431	13.166	1	.000	179.582
	SILL(2)	4.416	1.065	17.192	1	.000	82.768
	SILL(3)	2.679	.963	7.742	1	.005	14.567
	SILL(4)	2.455	.901	7.418	1	.006	11.641
	NASCON			8.457	4	.076	
	NASCON(1)	2.705	1.436	3.548	1	.060	14.959
	NASCON(2)	1.617	.851	3.615	1	.057	5.038
	NASCON(3)	-.688	1.178	.341	1	.559	.502
	NASCON(4)	.985	.752	1.715	1	.190	2.678
	NASWIDT			13.147	2	.001	
	NASWIDT(1)	-2.972	.824	13.003	1	.000	.051
	NASWIDT(2)	-2.442	.924	6.983	1	.008	.087
	PROG			14.325	2	.001	
	PROG(1)	-4.336	1.242	12.188	1	.000	.013
	PROG(2)	-2.714	1.231	4.858	1	.028	.066
	CHIN			3.215	2	.200	
	CHIN(1)	-2.697	1.578	2.921	1	.087	.067
	CHIN(2)	.119	.667	.032	1	.858	1.127
	Constant	2.218	1.577	1.978	1	.160	9.190

a. Variable(s) entered on step 1: NASO, SPS, INTEROR, SILL, SPINE, NASCON, NASWIDT, ZYGM, ZYGOSUT, PROG, CHIN.

As the original equation used both historic and modern samples, this may not reflect possible secular change occurring between the time periods represented in the collection. To further analyze secular change in nonmetric cranial traits, two further logistic regression equations were created using the five variables above (Table 3.8). Due to the same sample size in the modern African American sample, this was done using the enter method, meaning that all five variables were entered into the equation simultaneously to offer a final result. In these additional formulas, the Modern sample and Historic sample were considered separately and tested for accuracy first within group. Then, the regression formula for each were tested with data from the opposite group (i.e., the historic sample was used to test the modern formula and the modern sample was tested with the historic formula) to see if the accuracy rates were comparable.

For the modern formula, accuracy rates yielded 93.8% for the modern sample, with Euro Americans at 98.5% and African Americans at 87.2%. Table 3.9 shows the coefficients and constant for the formula. When the historic sample was tested using this formula, the accuracy rates reflected a substantial difference. Overall, accuracy for using the formula was 85.7% at predicting ancestry. In Euro Americans, it predicted ancestry correctly at 89.0%. For African Americans, accuracy was at 82.9%. There was an 8.1% decrease in accuracy when using modern crania to predict ancestry in historic skeletal material.

Table 3.9. Variables in the Final Logistic Regression Model for the Modern Sample. This includes individuals in the modern sample. This table shows the results for the five variables chosen for the logistic regression equation. They are listed with their coefficients (B values) as well as the constant (A) for the equation.

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	SILL			7.981	4	.092	
	SILL(1)	5.525	2.483	4.950	1	.026	250.923
	SILL(2)	4.418	1.842	5.749	1	.016	82.907
	SILL(3)	1.664	1.712	.944	1	.331	5.280
	SILL(4)	2.296	1.447	2.517	1	.113	9.937
	NASCON			1.137	4	.888	
	NASCON(1)	22.270	8745.307	.000	1	.998	4.695E9
	NASCON(2)	1.184	1.596	.550	1	.458	3.266
	NASCON(3)	.846	1.689	.251	1	.617	2.329
	NASCON(4)	1.480	1.427	1.075	1	.300	4.391
	NASWIDT			7.319	2	.026	
	NASWIDT(1)	-4.296	1.665	6.657	1	.010	.014
	NASWIDT(2)	-5.469	2.158	6.421	1	.011	.004
	PROG			9.902	2	.007	
	PROG(1)	-4.708	1.632	8.317	1	.004	.009
	PROG(2)	-2.201	1.571	1.964	1	.161	.111
	CHIN			1.449	2	.485	
	CHIN(1)	-6.097	8.144	.560	1	.454	.002
	CHIN(2)	-1.207	1.145	1.110	1	.292	.299
	Constant	4.186	2.995	1.954	1	.162	65.748

a. Variable(s) entered on step 1: SILL, NASCON, NASWIDT, PROG, CHIN.

For the historic formula, the overall accuracy was 91.3% for the historic sample. For Euro Americans, it yielded 89.0% accuracy while for African Americans, it was at 93.2%. Table 3.10 shows the coefficients and constant for the formula derived from the historic sample. When the modern sample was tested using this formula, the accuracy rates reflected a difference similar to the one seen when testing historic. Overall, accuracy for using the formula derived from a historic population on a modern sample was 86.6% at predicting ancestry. In Euro Americans, it predicted ancestry correctly at 84.6%. For African Americans, accuracy was at 89.3%. There was an approximately 5% decrease in accuracy when using historic crania to derive a formula to predict ancestry in modern skeletal material.

Table 3.10. Variables in the Final Logistic Regression Model for the Historic Sample. This includes individuals in the historic sample. This table shows the results for the five variables chosen for the logistic regression equation. They are listed with their coefficients (B values) as well as the constant (A) for the equation.

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	SILL			22.054	4	.000	
	SILL(1)	5.633	1.599	12.406	1	.000	279.407
	SILL(2)	6.000	1.435	17.494	1	.000	403.528
	SILL(3)	3.123	1.081	8.344	1	.004	22.723
	SILL(4)	2.107	1.070	3.876	1	.049	8.228
	NASCON			9.830	4	.043	
	NASCON(1)	3.628	1.689	4.612	1	.032	37.630
	NASCON(2)	2.672	1.009	7.018	1	.008	14.466
	NASCON(3)	.984	1.424	.478	1	.490	2.675
	NASCON(4)	.210	.913	.053	1	.818	1.234
	NASWIDT			5.019	2	.081	
	NASWIDT(1)	-2.232	.996	5.019	1	.025	.107
	NASWIDT(2)	-1.277	.941	1.842	1	.175	.279
	PROG			8.066	2	.018	
	PROG(1)	-2.086	.950	4.822	1	.028	.124
	PROG(2)	.336	1.160	.084	1	.772	1.399
	CHIN			2.154	2	.341	
	CHIN(1)	-.541	1.520	.127	1	.722	.582
	CHIN(2)	1.037	.858	1.461	1	.227	2.821
	Constant	-1.776	1.509	1.385	1	.239	.169

a. Variable(s) entered on step 1: SILL, NASCON, NASWIDT, PROG, CHIN.

CHAPTER 4. DISCUSSION

Racial categories have changed over time as the larger understanding of race has changed from biological to social (Littlefield et al 1982). Forensic anthropologists operate within this changing system to identify the dead using physical characteristics to find an analogous social category. The social underpinnings of race are especially important when considering secular change. Designations of racial categories, such as black and white, have changed over the last century and these social definitions have impacted reported race. This can be problematic when one accounts for the fact that biological ancestry may or may not correlate to self-reported race. Race is a social construct; it is not identical to genetic variation. Simply because human beings can be divided into categories based upon genetic differences, this does not mean that they are naturally divided into these categories (Gravlee 2009). Yet it is unwise to discard human variation as unimportant, especially in the work of forensic anthropologists. Race has a very real impact. Even though racial categories are primarily socially constructed, they still have biological consequences (Gravlee 2009). It is the goal of forensic anthropology to negotiate between social and biological confluences of race with the ultimate goal of the identification of decomposing and skeletal remains for law enforcement and medico-legal investigations.

In recent years, it has become increasingly obvious that estimation of ancestry based on the skeleton is neither straightforward nor simple but instead relies upon experience and understanding of the more subtle aspects of human variation (Hefner 2009). The purpose of this study was to further knowledge of how nonmetric variation in the human crania can assist forensic anthropologists in matching skeletal remains to self-reported ancestry in medicolegal death investigations.

To explore the topic, it was first important to provide a list of standardized definitions for traits and the character states used to describe them, drawing from *ad hoc* data and anecdotal notations in previously published literature (Table 2.2). Then, the validity of morphoscopic traits for ancestry estimation was explored by assessing the distribution of trait frequencies between two self identified population groups in the United States: African Americans and Euro Americans. Once the distribution of these traits was re-examined from expected frequencies found in older literature, a logistic regression equation was formulated to propose a suite of traits that prove best in the estimation of ancestry between these two population groups.

From there, it was of interest to examine what effects secular change has had on nonmetric trait distribution of the crania. Secular change in cranial nonmetrics can have a profound effect on ancestry estimation, especially if these changes significantly change the distribution of certain traits used by forensic anthropologists. By exploring this change and considering some of the underlying causes for it, it is possible to develop a greater understanding for the issues of race, ancestry, and human variation.

4.1 Ancestry Estimation

The primary purpose of this study was two-fold: first to reexamine the distribution of nonmetric variables classically associated with the estimation of ancestry in the literature and secondly to document any evidence of secular change in the results. It was theorized that while differences in trait frequency distributions between populations would exist, that they would be less distinct and separate than earlier research suggested. Additionally, it was an attempt to further explore standardization of nonmetric traits for ancestry estimation. Definitions were provided in the text for each trait assessed. Eleven of which were directly taken from Hefner

(2009) while others were taken from informal descriptions provided by the authors listed in Table 1.2.

Of the 27 traits used in the study, 24 were associated with ancestry estimation. Of those, 12 were found to exhibit significant differences in distribution between African Americans and Euro Americans. No single individual displayed all character state of traits that previous studies established as being typical of either ancestry group. In short, the typical human being does not exist in the frequency or stereotypical quality that early research has suggested. Comparing nonmetric traits historically associated with and expected within the ancestry groups (Table 1.1) with the results of the study yielded an interesting reflection on human variation.

Overall, traits associated with the midfacial region are the best indicators of ancestry. Ten traits were found to be significant: nasal overgrowth, supranasal suture, interorbital breadth, subnasal margin, anterior interior nasal spine, nasal bone contour, nasal aperture width, zygomatic projection, zygomatic suture shape, and orbital shape. Of those, all of them are located in the midfacial region of the skull. Two significant traits were related to the alveolar area: prognathism, and chin shape. A number of these did correspond with the traditional traits associated with ancestry. Traits associated with overall nasal form - the nasal sill, nasal aperture width, nasal bone contour, and nasal spine – were found to be reliable indicators of ancestry as was interorbital breadth. When including traits of the palate and alveolar area, chin shape and the degree of prognathism were also found to be indicative of ancestry between the two groups. The shape and orientation of the eye orbits were also significant among groups. Results of this study show African Americans generally have a wide nasal aperture, low oval-shaped nasals with a wide interorbital distance, nasal guttering, and a small nasal spine. They are also characterized by prominent prognathism.

These were consistent with earlier findings as most Euro Americans and African Americans exhibit certain traits that are typical of their ancestry groups. These traits do have the tendency to be specific to each ancestry group and can be used to distinguish between African and European descent in American populations. Chin shape in African Americans is variable but found to be rounded more frequently than blunt and rarely bilobate.

By contrast, Euro Americans were shown to have high nasals with a narrow interorbital distance, a prominent nasal spine, a narrow nasal aperture, and the presence of a nasal sill. There is little or no prognathism. While the Euro American sample did show a significantly higher number of bilobate shaped chins than the other, the largest portion of mandibles were scored as blunt. This overlap indicates that while chin shape does exhibit certain trends across populations it is not as reliable for a means of ancestry on its own.

There were several traits generally associated with ancestry estimation that were found to hold no significance when compared between the samples. Robusticity associated with the malar tubercle, classically linked with those of European descent, was found to be nonsignificant across the two groups. This aligns with earlier studies testing the validity of this trait (Hefner 2009) and suggests that this variable be discarded as one used in ancestry estimation in the future. The presence of a metopic suture has long been associated with populations of European descent. However, this study found that the metopic trace was found inconsistently in both ancestry groups and nonsignificant in distribution. It was found in less than 10% of both groups with nearly the same distribution. This refutes earlier literature (Rhine 1990) for using the trait as a marker for ancestry in a forensic context. While it was found to be nonsignificant, the presence of an open or visible supranasal suture was found more frequently in the Euro American population. Nasal overgrowth was also found at a significantly higher percentage in Euro Americans though the trait itself is considered to be associated with Asian ancestry. Since no Asian Americans or Native Americans were included in this study, it would be of interest to note a comparison among groups with that addition as frequencies for these populations.

Traits associated with the cranial vault were found to be much less reliable for use in ancestry estimation. The presence of an inion hook, a trait purported was found in Euro American groups (Rhine 1990; Gill 1995; Klepinger 2008), was found infrequently in both populations and not to any significant degree. Post-bregmatic cranial depression, a trait that has been associated with African Americans, appeared in the study equally infrequently among both groups. This is in direct contrast with earlier studies done by Rhine (1990) and Hefner (2009). It should be noted that Hefner (2009) included both Africans and African Americans in his sample group and while this provided a larger sample size, it also confounded the results of the study. African Americans are not the same population group as Africans. This distinction should be made in future studies as these are distinctive populations and changes may be evident between them. The same should be noted for Europeans and Euro Americans. While they may share certain ancestral similarities, they do not share identical genetic and environmental influences in contemporary times. As such, it is inadvisable to cluster them together in future analyses with only the assumption that they are identical groups.

4.2 Regression Formula

While 12 traits were found to be significant between ancestry groups, this does not answer which are best predictors of ancestry. It is impossible to predict ancestry of an individual based upon a single variable, much the same way this is true for sex or age. No single trait is adequate to describe or document the degree of human variation that exists both within and between population groups of differing ancestral origins.

To approach the problem, a formula was created using logistic regression to incorporate categorical data into a statistical form. The formula created from the twelve variables found to be significantly distributed among the two groups was:

Log-odds = A + B_1(Nasal Bone Contour) + B_2 (Nasal Sill) + B_3(Nasal Width) + B_4(Prognathism) + B_5(Chin Shape)

where A is the constant and B values are the coefficients. The formula finds the log-odd values that are then used to determine the odds by taking the exponent of the log-odds. The odds yield a probability value that will always fall between one and zero and is a measure of how likely an event (in this case, the ancestry of an individual from the sample being either African American or Euro American) is to occur. For this formula, the odds of the event (ancestry) were established to be Euro American (0) and African American (1). Thus, probabilities below 0.5 are more likely to be Euro American and probabilities above 0.5 to be African American. The strength of probability for either group increases as the values approach zero and one. This formula proved to be the most accurate method among the research methods used in the study with 92.6% accuracy for African American males and 93.6% for Euro American males. Overall, the formula accuracy was 93.1%, To illustrate the use of the regression formula, sample #113 was randomly selected for an example. The value for this individual were:

Nasal bone contour = 3
Nasal Sill = 2
Nasal Width = 3
Prognathism = 0
Chin Shape = 3

The constants and coefficients used in the equation are based on the logistic regression output located in Table 3.9. For categorical variables, the coefficient included in the equation depends on the score for each individual. For this example, the nasal sill is scored as 2. The coefficient that corresponds to the score of two was used and the X value entered was one. The reference score for each in this equation was the highest score, meaning that there is no coefficient for those individuals with the highest scores in each category (for example, in nasal aperture width, a score of 3 would give a coefficient of zero). The actual score for each trait was not entered as the X value because categorical values in equations are based on a binary code of present or absent for each score.

For this example, the equation is:

Log-odds = 2.218 + (0) + (1)4.633 + (0) + (1)-4.337 + (0)

Log-odds = 4.52

Odds = 91.835 (computed by taking the exponent of the log-odds value)

From this point, the odds value must be converted into a probability to allow the determination between African American and Euro American. To do this, the following equation is used:

Probability = odd/(odds +1)

The probability for this individual is 0.989 which makes it very likely that the individual is African American based on the cut-off value is 0.5. Demographic information about sample #113 reveals that it is, in fact, African American.

Logistic regression was used for this study because ancestry was a binary variable (as individuals of two ancestry groups were used there were only two outcomes), the technique can be modified to incorporate more than two ancestry groups with the use of factorial logistic regression in future research. The inclusion of other self-identified racial groups in America would ultimately be preferable to further standardize methodology. Hefner (2009) reports success with estimation using Bayesian analysis for multiple population groups but his methodology has not been explored in depth at this point in time (Komar and Buikstra 2008).

4.3 Sexual Dimorphism and Ancestry.

The human cranium is the third most sexual dimorphic area of the human body after the pelvis and the long bones (Spradley and Jantz 2011). In general, males are considered more robust while females are more gracile (Walker 2009; Rogers 1999; Byers 2010). Anecdotal evidence mentioned in literature mentions that individuals of African or Asian ancestry show less robust brow ridges and muscle attachment sites on the skull than those of European ancestry (Byers 2010). Hooton (1947) observed postcranial differences following the same trend with African Americans having more slight muscle attachments than Euro Americans. Four cranial traits generally involved assessing sexual dimorphism in the skull were chosen for inclusion in this study to address this assumption by comparison between two ancestry groups: occipital protuberance, mastoid process length, glabellar projection, and suborbital margin (Table 3.5).

Overall, males of both ancestry groups were assessed as being robust and scored higher than the ranged reported for females, matching earlier studies (Buikstra and Ubelaker 1994; Walker 2009). Of those four traits, statistically significant differences between ancestry groups were found within glabellar projection and mastoid process length. The glabellar region in Euro Americans was found to be more robust than in African Americans, confirming the claims purported in earlier anecdotal research (Beyers 2010). It should be noticed that this difference was slight and both groups fell within the standard character states for males previously established.

Contrary to earlier studies, the length and overall rugosity of the mastoid process was found to be greater in African Americans who consistently scored higher on the morphological evaluation than Euro Americans. This is in direct contrast the assumption of increased muscle attachment robusticity within those of European descent. While these two traits proved significantly different from one another, it should be noted that these differences were not enough to estimate ancestry based upon either trait in conjunction or alone. The other two traits, occipital protuberance and suborbital margins, showed no differences between the groups. Yet these findings remain important because they refute the idea that African Americans males are skeletally less robust or rugged than their Euro American counterparts. So often in early forensic anthropology, small samples were inflated to encompass the norm for a group as a whole. In this case, we find that while one trait is seen to be more robust among Euro Americans as the supposed trend would dictate, the other three do not share that tendency with either non-significance between groups or with a trend indicating that rugosity may be correlated in the other direction with an increased robusticity in African Americans.

4.4 Secular Change

In this study, Euro and African American individuals from the Terry Collection (individuals born in late 19th century to early 20th century) were compared to those of the Bass Donated Collection and the FACES Lab (individuals born in the 20th century) within their respective ancestry groups. All individuals were either of self-reported ancestry or assigned ancestry at autopsy. While it should be of note that assigned ancestry could be problematic, it also provides a good reflection of the social concept of race for the time.

Using metric analysis to examine secular change, Jantz (2001) found an overall narrowing of the face and an increase in cranial vault height. This was not reflected in the current nonmetric analysis, though this may be due in part to the features analyzed in the study. It may be that while the metric size reflected a narrowing, change in shape was not reflected in the same manner. This may simply be due to the nature of morphoscopic traits. After all, most traits are assessed in relation to the face as a whole. If the entire face is narrowing, then comparative biology shows fewer changes without a metric assessment. In both Euro and African Americans, the majority of traits associated with the midfacial region appeared to show no significant changes. These findings echo those earlier and indicate that the midfacial region remains a good choice for ancestry estimation. However, there were a number of traits that did show evidence of secular change in the samples.

Both Euro and African Americans groups displayed a significant change in orbital form. Euro Americans showed an increase in squared, laterally sloped eye orbits and a decrease in squared, nonsloped orbits over time. African American groups showed an increase in laterally sloped orbits as well, though the primary shape remained rectangular more frequently than square or rounded. This result indicates a trend in lateral sloping of the orbits. While this is interesting, orbit orientation has not previously been studied in reference to metrically analyzed secular change; this finding may require further investigation to account for this change in orientation. Euro Americans showed a significant decrease in the prominence of nasal spine length over time, though slight, that was not reflected in other traits in the nasal form as width of the nasal aperture, nasal sill, and interorbital breadth remained unchanged for both groups. There was a change in nasal bone contour in the African American samples, however, while no significant changes existed between the Euro American samples. There was a decrease in roundedness and an increase in triangulation of the nasal bone contour with time.

Alveolar prognathism showed a prominent change among African Americans in the two samples, becoming markedly less pronounced over time. Chin shape was also of note. In European Americans, the modern sample showed a significant increase in bilobate, prominent chins and a decrease in blunt or rounded chin shape. While changes in the African American sample were not statistically significant in turning the tests, the researcher did note a shift in frequencies while assigning scores for each individual. These differences are reflected in the degree of expression. African Americans showed an increase in blunted, prominent chins from recessive, rounded chins from the Terry Collection to the Bass Donated Collection. However, these changes were not statistically significant. In many cases, it was a distinction that was not reflected in the score of the trait but rather in some aspect of the appearance. Yet we should be cautioned against putting too much emphasis on further anecdotal data, as it has little use in the practice and development of actual technique in forensic anthropology. However, it might prove an area of further research when compared to a wider sample of ancestry groups and a larger sample of current groups used.

Jantz and Meadows Jantz (2000) concluded that crania exhibit change over time in a similar fashion to the long bones, albeit at a slower rate. It appears that not all aspects of crania are changing at the same rate, nor are they changing similarly between ancestry groups. There is more change present in the lower portion of the mid-facial region of African Americans than in Euro Americans, as the increase in prominence in the chin and a decrease in prognathism as the face. This may be indicative of the change that Jantz (2001) saw in overall narrowing of the face but the nasal form was otherwise not affected by this.

With change evident in nonmetric trait distribution, the implication that historic samples can be used as a control sample for modern forensic investigation also requires investigation. In this study, two logistic regression formulas were devised from the one discussed in the previous section. The original formula (Table 3.8) was created using both historic and modern samples; these other two (Table 3.9; Table 3.10) were time period specific. Using only the historic sample in the regression analysis, the ancestry for that group could be estimated with 91.3% accuracy (89.0% for Euro Americans and 93.2% for African Americans). Using the modern sample in the same analysis yielded ancestry estimation accuracy rates of 93.8% within that sample, with 98.5% for Euro Americans and 87.2% for African Americans.

Testing the modern sample in a formula devised with a historic group, the total accuracy was 86.6% (84.6% for Euro Americans and 89.3% for African Americans). This is a 5% decrease in accuracy when compared to methods devised for a population specific analysis. Testing the historic sample in a formula devised with a modern group showed 85.7% overall accuracy (with

89.0% for Euro Americans and 82.9% for African Americans). This is an 8% decrease in accuracy when compared to the formula created from a contemporary sample group.

There is a 5-8% decrease in accuracy rates when using a sample not contemporary to create estimation techniques for an unknown individual. This decrease is further indication that secular change is occurring. For each of the groups, accuracy rates show differences between the samples. Time period specific samples show greater accuracy rates than those devised from non-contemporary samples. Some of this loss of accuracy in testing the modern samples against historic and vice versa is due to the fact that these samples did not contribute to the model. However, some change may have another meaning.

Table 4.1 shows the distribution of accuracy across the four formulas devised for specific time periods. When using historic regression formulas to classify modern individuals, accuracy in the classification of Euro American ancestry is reduced because too many Euro American individuals misclassify as African American. When using the reverse, with using a modern regression formula to classify historic, the opposite is true: African Americans are classifying as Euro Americans, decreasing the accuracy of their identification. This appears to be counterintuitive given the secular trends identified by earlier analysis. With the decrease of prognathism and the change in nasal contour among individuals of African American ancestry, it would stand to reason that the opposite would be true: that more modern African Americans would misclassify as Euro American using the historic regression formulas.

Table 4.1 Accuracy rates for time period dependent regression formulas.

	Euro	African
Modern Sample tested with Historic Formula	84.6	89.3
Historic Sample tested with Modern Formula	89.0	82.9
Modern Sample tested with Modern Formula	98.5	87.2
Historic Sample tested with Historic Formula	89.0	93.2

Some of this misclassification may be due to the reduced sample sizes used in the creation of the regression formulas. The original regression formula combined samples to provide the most statistical power. However, when these were groups were split for the time dependent analyses, there was an added disadvantage to the statistical tests. The modern formula was created with n=112 and the historic was with n=161. These sample sizes were reduced due to individuals missing scores in one of the five variables and thus not being included in the analyses. Thus the misclassification of African Americans seen in the historic sample may be due to smaller sample size for each of these equations.

However, this analysis is further data that stands in direct opposite of the idea that human begins are completely phenotypically dichotomous. While these five traits may show significant differences between the groups, only two of them (prognathism and nasal bone contour) show any evidence of secular change. It may be that the formulas are not reflecting all secular change seen in the skeleton. This may be more beneficial to forensic identification techniques, as a number of the traits used prove to be more consistent over time.

CHAPTER 5
CONCLUSIONS

Since the early 1900s, anthropologists have had an interest in distinguishing ancestral groups from their skeletal remains. While anthropologists have largely reached the consensus that race is not a biological construct, they still use race (or ancestry) as a tool for identification practices in forensic anthropology. The change in practices has shifted far more subtly than the change in what race means which, at this time, refers to a social construction and is no longer a means to justify scientific racism. Instead of a racial category, forensic anthropologists work to supply information that may match an ancestral group common in the current American populations with unknown human remains. The purpose of this study was to reexamine the affects of ancestry on the expression of nonmetric traits in male crania with consideration given to the effects of secular change. The results of the study do show that significant differences do exist between ancestry groups. Of the 27 traits used in this study, 12 were considered significant. Of those 12, a logistic regression equation was created from five traits (nasal bone contour, nasal sill, nasal width, prognathism, chin shape) to develop an suite of traits that can be used to estimate ancestry with a 93% accuracy rate.

However, the outcome of this study has implications for the practical application of nonmetric variables used by forensic anthropologists to estimation ancestry in American populations. The classic distribution of traits developed in the first part of the twentieth century no longer holds true in a modern population. Many early traits adapted from Hooton’s original Harvard List have little significance in the possible identification of African American or Euro American individuals. Yet others have similar distributions to that shown in earlier studies (Reichs 1987; Rhine 1990; Gill 1995; Hefner 2009), particularly in the midfacial region of the skull. Extreme expression of traits associated with ancestry are not as reliable as the old, dichotomy based system of estimation suggests. More individuals fall within gradations of an expressed trait instead of at the more polarized ends of the spectrum associated with the typical morphology of their ancestry group. It is important to look at the cranial form, especially at the regions identified as being good indicators of ancestry, as a whole and to work upon generalizations instead of single traits.

5.1 Standardization in Forensic Anthropology

Standardization in forensic anthropology is lacking. Generally speaking, few cohesive standards exist across the board for nonmetric ancestry estimation. The most common study cited for ancestry estimation is Stanley Rhine's 1990 article "Non-Metric Skull Racing." This article has been used as a guideline for ancestry estimation since its publication. As previously discussed, this article has a very specific bias in both sample size and methodology. Rhine developed a suite of traits useful in characterizing three distinct population groups in the United States: "Caucasoid," "Southwestern Mongoloid," and "American Black." He included both Hispanics and those of European descent in this "Caucasoid group" while the "American Black" sample was five skulls and two casts of unmentioned origin. This lumping has furthered the confusion in understanding of population dynamics. Hefner (2009) added to possible issues by using African and African Americans as a single population which may also account for the non-significance in post-bregmatic cranial depression and metopic suture shape in seen in this study.

No standardized list of traits exists for ancestry identification in the United States. While there are several variants with similarities, none have been tested to withstand the Daubert criteria (Albanese and Saunders 2006). While this has not been problematic to this point, it does not rule out the possibility of this occurring in the future. Forensic anthropologists should be aware that the need for standardization still exists. While the current study included 23traits (with another four correlated with cranial robusticity), this does not encompass every possible trait that may be valid among those presented by Rhine (1990) or Hauser and de Stefano (1989).

While many listings of traits contain similarities, the same cannot also be said for definitions for such traits. In my own experience as a student of forensic anthropology, I have run across several differing methods to assess nonmetric variables many of which are in direct opposition to one another. Efforts by Hefner (2003, 2009) to provide a single, efficient methodology across the field should not be the last of these in the field.

As professionals in forensic science, anthropologists should be held to a high standard for methods and practice of all procedures. While Hefner (2009) provides a standardized set for eleven measurements that are included in this analysis, there are a vast number in the literature that have no documented distribution apart from those few studies with sparse definitions and even sparser use. The field has often relied on the "oral tradition" created by Hooton for establishing the training and development of nonmetrics in the field (Hefner 2009). While these methods of instruction are best when teaching future students of anthropology, the methodology and emphasis upon which traits are most reliable taught should vary less between instructors.

To decrease the subjectivity in scoring morphoscopic traits, a standardized set of definitions was included detailed definitions with visual guidelines for each trait used for analysis. Hefner (2009) reports less interobserver error with the use of illustrations or photographs for each character state in nonmetric traits. The illustrations and definitions developed for this study were based in part by earlier work by a plethora of authors (Table 1.2) and offer concise specifics for ease of replication by other researchers. It is hoped that these criteria may offer a foundation for further development of trait standardization in a larger sample across populations.

5.2 Morphoscopic Traits for Ancestry Identification

Twenty-seven morphoscopic traits were used in the study. Of those, 14 were found to show significant differences between populations. Variation in the midfacial region was shown to be the best indicator of ancestry. Of the significant traits, ten of them were located in that proximity. Two were in the alveolar area and the final pair were included in traits examined for comparison of cranial robusticity. None of the morphoscopic traits of the cranial vault were found to be significant.

Of these 14 traits, ten located in the midfacial skeleton were: nasal overgrowth, supranasal suture, zygomatic projection, zygomaxillary suture shape, interorbital breadth, orbital shape, nasal aperture width, nasal bone contour, nasal sill, and the nasal spine. Prognathism and chin shape were also significant. The majority of these traits are associated with the nasal form or surrounding regions with the noted exception of the two alveolar traits. This supports earlier use of this area as the focus of ancestry estimation techniques.

Among the four traits scored for cranial robusticity, glabellar projection and the mastoid process were significantly different in the comparison as well. While these two traits are often used in the conjunction with sex estimation, they do show some differences between ancestry groups. Mastoid size is shown to be slightly more robust in African Americans while the previous literature shows the opposite trend with greater robusticity in Euro Americans. Both groups fell well within the estimated range for males. However, FORDISC does not show this finding supported in a metric analysis when compared to the mean scores in the Forensic Data Bank. As such, it cannot be shown conclusively that nonmetric cranial robusticity is linked to ancestry to a measurable degree that can be used in a morphological estimation.

In order to further standardize ancestry estimation from nonmetrics, logistic regression was used to establish the best predictors for ancestry. Five variables from the original 12 selected in the final formula: nasal bone contour, nasal aperture width, nasal sill, prognathism, and chin shape. Three of these are related to nasal form while the other two are alveolar. The use of the present regression formula offers 91-94% accuracy in accurate estimation of ancestry between African Americans and Euro Americans. By including dental traits (where available) or more mandibular traits listed in literature (Rhine 1990; Gill 1995; Klepinger 2008) in future studies, this accuracy may be increased.

Results of this study indicate that earlier trends reported in ancestry estimation are valid. The use of traits associated with nasal form provides the most reliable indicators of ancestry and should be used whenever possible. Traits historically associated with ancestry: post-bregmatic cranial depression (supposedly found frequently among African Americans), metopic suture or inion hook(both traits associated with Euro Americans), and malar were shown to be non-significant for the estimation of African Americans and Euro American.

5.3 Secular Change in Nonmetrics Traits

It has been previously established that the cranium has exhibited a number of changes over time (Jantz 2001; Jantz and Meadows Jantz 2000; Gravlee et al 2003) as has the postcranial skeleton (Meadows Jantz and Jantz 1999; Ruff 2002). Jantz and Meadows Jantz (2000) made the observation that while size changes are evident in craniometric analysis, these are less apparent than the change of shape that occurs. Interestingly enough, this is mirrored in differences seen in nonmetrics as well.

In this study, 27 traits were commonly used for ancestral estimation were compared between two time periods. Samples were taken from the Terry Collection (individuals born in late 19th century to early 20th century) and compared to that of the Bass Donated Collection (individuals born in the 20th century). Analysis demonstrated a significant change in orbital form, anterior inferior nasal spine, zygomaxillary suture, chin shape, malar tubercle, glabellar projection, and suborbital margin for Euro Americans (Table 3.6). For the African American sample, significant differences were found in orbital form, prognathism, malar tubercle, and the palatine torus (Table 3.7).

Overall, these changes reflect a trend that appears to move away from the discrete dichotomy that has defined ancestry techniques while many traits still remain within the categorical range typically associated with the ancestry group. The shift in these traits is moving toward the median of character states rather than polarizing on opposite sides. This is something that is seen in both Euro and African Americans. While the argument might be made that African Americans look more "white" in recent times, this is simply untrue and carries some connotation of the older Eurocentric ideals. The United States population remains a heterogeneous one even as racial groups appear to be showing osteological trends that follow certain patterns. However, this is not entirely uncharacteristic of populations in general. As these groups have changes moving in the same direction, it may show the same genetic and environmental factors are at play upon both, though further exploration of those are imperative to discover what those might be.

The contribution of gene flow, and the slowly weakening of social and geographic barriers that have contributed to mate selection in the past, also factor into some of these changes. While most human mate selection still remains to be within the constrictions of sociocultural racial groups, the increased genetic admixture among and between groups within the United States will lead to an increasing homogeneity within the population. While ancestry estimation in forensic anthropology is still influenced by social race, this may decrease in the future as the lines between racial groups begin to further deteriorate.

The Terry and Bass Donated Collections span only a relatively short period of time in human history, yet remarkable environmental and social change has occurred within this period of time. As Boas (1940) and then Gravlee and Sparks (2003) have shown, there is high plasticity in the skull and can undergo significant change in a short amount of time under the right conditions. Changes in environment (such as nutrition or general living conditions) can have a dramatic impact on mortality rates or disease prevalence. Social changes have also impacted the flow of genetic exchange among populations. The population of the United States does not fall into discrete categories. Even if true races existed at some time (a theory of dubious origin in itself), these races would no longer be pure or pristine in the modern context. Typically, human beings engage in mating patterns that are largely endogamous, meaning that they date largely within their own racial or ethnic groupings. Human mating is non-random and historically has been largely within sociocultural racial groups, often with some level of discrimination based on cultural practices or displayed phenotypic characteristics (O'Neil 2006). However, as globalization becomes more common, it also becomes more common for interracial mating to occur. Nonrandom mating patterns begin to change, reflecting this globalization and the changing social landscape that allows for more freedom in mate choice, this allowing for both endogamy to occur in certain localities while exogamy in others. This increase in genetic admixture within the larger population may have a significant role in these changes, though it is difficult to assess in skeletal samples due to the limited amount of data present for each individual.

Additionally, there has been a shift in forensic anthropology towards standardization and the understanding that population specific methodology should be employed when possible. This has been seen previously in stature estimation, as formulas devised from individuals in the early half of the 20th century are not as accurate in modern estimations as those devised from a later 20th century sample. In nonmetric traits, there is a 5-8% decrease in accuracy rates when methodology is devised from non-contemporary samples taken from this study. While this change may seem minute, it further indicates that using historic methods (even those that have been devised within the last century) maybe be detrimental to the providing the most accurate information in medico-legal investigations and highlights the need for a standardized technique that is time depth appropriate.

5.4 Future Research

This study is not designed to be the final word in ancestry estimation via nonmetric variation. While it is hoped that it will provided some insight on the origin, use, and future of the techniques, it does not answer all questions that the sheer expansive range of human variation present in the skeleton. The scope of this study was limited due to a number of factors that should be addressed in future research.

Only males were used in this specific study due to the low number of African American females available for study. In the Bass Donated Collection, there are less than ten African American woman represented among over 900 skeletons. While the Terry Collection has a larger number available, the lack of a comparable modern sample might further skew results and greatly diminish the power of the tests that could be used. With a larger sample size, it might be possible to examine the affects of sexual dimorphism on the traits and see if the distribution of traits changed between sex groups.

While the current assumption is that this is not the case, there has been research that suggests some sex differences exist metrically among ancestry groups, specifically that in stature estimations (Stephens 2000). Critical examination of nonmetric trait distribution among groups may prove to support previous assumptions or to lead to the discovery of differentiation of the sexes even in ancestral indicators of the crania. As no change in cranial robusticity was seen between the groups, which generally indicate sexual dimorphism, it may be unlikely that sexual differentiation would affect ancestry estimation. However at this period in time, this study offers no conclusive evidence in either direction.

Additionally, it must be pointed out that this study focused primarily upon two groups in the United States: African Americans and Euro Americans. These two groups were chosen due to their prolific use in studies and the availability of skeletal material. In the United States, there are far more skeletal collections that focus upon these two groups; this is unsurprising given the historic demographics of the American population. However, the racial and ancestral demographics of the United States are far more complex. The exclusion of other ancestral populations may lead to bias in the analyses results. If this study were to be replicated, it should include a more realistic view of the varied groups within the country. At the very least, nonmetric variation in Asian Americans and Hispanics should be studied, both of which were excluded from this study based upon availability of skeletal material.

5.5 Conclusions

The meaning of race has changed; it is no longer a biological imperative but rather a confluence of biology, culture, and self-identification. So to have the defining characteristics that shape population groups once referred to as race. Now, these groupings are made more by cultural distinctions than biology. While the understanding of race has changed, so too has human morphology.

Standard discrete trait analyses have been developed on samples from North America and many of the samples used in earlier studies were small (Rhine 1990) or largely composed of individuals born in an earlier century or another continent (Rhine 1990; Corrucini 1979; Hefner 2009). In many cases, this may affect the distribution of traits and confound the actual frequencies for ancestry groups. Additionally, most literature in nonmetric evaluation, with the noted exception of the more recent article by Hefner (2009), has not well defined these traits or may only warrant anecdotal evidence in the text. In order to provide the best assessment of nonmetric variable distribution, it is imperative to develop standards shared across the field. This has proven problematic due to the oral tradition for instruction and often conflicting peripheral traits used in source material. Hefner (2009) suggests that forensic anthropologists typically estimate ancestry estimation based upon generalizations in shape and size of the skull and then assign character states to nonmetric traits ad hoc to provide a basis for that estimation. Experience does play a role in the understanding of human variation from the skeleton and should be considered when developing methodology. This can be said for many of the techniques used in forensic anthropology but that does not negate the need for more precise methods and a better understanding of the expression of these traits. Standardization can be accomplished in a number of fashions. Better documentation in the literature to provide both consistent, concise definitions and expected frequencies for each trait would provide researchers with a better indication of what traits they should expect to see and are less likely. The inclusion of standard drawings that provide visual indicators of character states of expression for each trait would provide more consistency in scoring the traits (Walker 2009; Hefner 2008). Overall, researchers need to recognize that populations are not polarized in trait distributions, not is there any trait which does not share overlap between ancestral groups.

Ancestry estimation via morphological nonmetrics remains a valid method in forensic anthropology. In many cases it is preferred because it does not require expensive laboratory equipment or computer software and has the added benefit that it can be done quickly in the field. Changing the meaning and understanding of race has also changed our understanding of forensic methods used to estimate it. It is imperative to continue our investigations of these changes to provide a better comprehension of human variation.

In conclusion, this study examines several aspects of nonmetric variation in the human crania typically used for identification purposes. Nonmetric variation does exist between population groups, specially seen in the African and Euro American samples in this study. Nonmetric can be used to differentiate groups from one another if employed properly and if the correct traits are used. Additionally, it is important to recognize that while variation exists and can be used to make qualifications of ancestry that correlate to social race, the categorical race is a construct of society in itself. As these categories undergo increasing flux and change, anthropologists must consider how best to focus their own research to be more consistent with these changes.

As it has been established that secular change is occurring in the crania, it is important to note that this change is happening both metrically and in morphoscopic traits. The intersection of forensic anthropology and secular change requires further study and interpretation in order to evaluate the changing understanding of human variation as well as the change in variation as well. Methodology in forensic research must reflect the current population if it is to be used consistently and for the most accurate results. Even the knowledge that secular change is occurring in these traits give forensic anthropologists more information with which to further their investigations.

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